INORGANIC CHEMISTRY
FOR
ELEMENTARY CLASSES.

BY W. A. SNAITH, M.A., Ph.D., F.E.I.S.,
Government Science Teacher.

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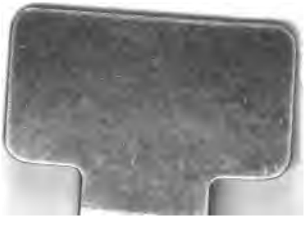

INORGANIC CHEMISTRY

FOR

ELEMENTARY CLASSES

DESIGNED CHIEFLY FOR USE IN THE ELEMENTARY STAGE OF CLASSES IN CONNECTION WITH THE SCIENCE AND ART DEPARTMENT, SOUTH KENSINGTON.

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PREFACE.

This little work has been prepared in the hope that it may be found useful to the Students of Chemistry Classes in connection with the Science and Art Department. It is principally a compilation from various works on Chemistry, but more especially from Mr. Buckmaster's *Inorganic Chemistry*, revised by G. Jarmain. The questions given at the foot of certain pages, and at the end of the book, have all been selected from the Examination Papers of the Science and Art Department; and as an answer to each question, as a general rule, may be found on the same page as the question, it is believed that this will prove of great value to students in giving them some idea of what will be expected from them at the examination. The whole of the thirty-six questions (with three exceptions) given in the elementary stage during the three years that Dr. Frankland has been the Examiner to the Department, together with about one-half of those given in the advanced stage, appear in the work. Full solutions of all the questions involving a knowledge of Arithmetic have been given in the belief that they will be of some service as examples.

DEFINITIONS.

ABBREVIATIONS USED.—Sc. Ex., Science and Art Department Examination; E, elementary stage; A, advanced stage. The numbers at the end of the questions refer to the numbers of the paragraphs where the answers may be found.

1. **Chemistry** is that science which treats of the laws which regulate the constitution of matter, and of the processes employed in producing changes in its composition.

2. **An Element** (called also by the various names, Simple Matter, Simple Substance, and Elementary Body) is a substance which contains only one kind of matter, and which, therefore, cannot be resolved into any simpler form. There are at present sixty-three elements known.

3. **A Compound** is a substance which contains two or more elementary bodies held together by the force of chemical affinity, and whose properties are different from those of the elements of which it is made up.

4. **A Mechanical Mixture** is made up of two or more elementary or compound bodies,

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Sc. Ex., 1870, E.—What do you understand by the terms "element," "oxide," "metal," and non-metal"? 2, 22, and 29.

Sc. Ex., May, 1861.—What is the difference between a chemical compound and a mechanical mixture? 3 and 4.

Sc. Ex., 1866.—Give the characters which mark the difference between "mechanical mixture" and "chemical compound." 3 and 4.

which are not combined by the force of chemical affinity, and whose ingredients retain their individual properties.

5. **Chemical Affinity** is that power or force by which bodies unite chemically. This force is exerted between fixed and definite quantities, or proportions of the elements, or between multiples of such quantities.

6. **An Atom** is the smallest portion of an elementary body which can enter into, or be expelled from a compound, or which can exist in chemical combination, and it is indivisible by chemical means.

7. **The Atoms of the Elementary Bodies** in the gaseous state, with five exceptions, are assumed to be all of the same size, but of different weights; this difference being expressed by the atomic weights of the elements. The five exceptions are, Phosphorus and Arsenic, whose atoms are half the size; and Zinc, Cadmium, and Mercury, whose atoms are double the size.

8. **A Molecule** is the smallest quantity of an element or compound which is capable of separate existence, or which can exist in the free or uncombined state.

9. **All Molecules** are of the same size. The following are examples of elementary molecules:

Sc. Ex., 1866.—Define the difference between "molecule" and "atom," and give examples to show the distinction between the two. 6, 7, 8 and 9.

Sc. Ex., 1869, A.—Define the terms "atom" and "molecule" in their modern acceptation. 6 and 8.

Monatomic molecules, containing one atom; zinc, cadmium, and mercury.

Diatomic molecules, containing two atoms; hydrogen, chlorine, bromine, iodine, fluorine, oxygen, nitrogen, sulphur.

Triatomic molecules, containing three atoms; ozone (allotropic oxygen.)

Tetratomic molecules, containing four atoms; phosphorus and arsenic.

Hexatomic molecules, containing six atoms; sulphur (at temperatures but little removed from its boiling point)

10. **The Molecules of Compounds** occupy the same volume as one molecule of hydrogen, no matter how many volumes the constituents may measure.

11. **The Atomic Weight of an Element** is a number which is made to represent as far as possible,

First.—The smallest proportion by weight in which the element enters into, or is expelled from a chemical compound; the smallest weight of hydrogen so entering or leaving a compound being taken as unity.

Second.—The weight of an element in the solid condition, which at any given temperature contains the same amount of heat as seven parts by weight of solid Lithium at the same temperature.

Third.—The weight of the element which, in the form of gas, occupies under like conditions of temperature and pressure the same volume as one part by weight of hydrogen.

12. **The Atomicity of an Element** (called also, Equivalence or Quantivalence) is the atom-fixing or atom-replacing power of an atom of that

element. It is also said to be its chemical value in exchange; the atom of hydrogen being taken as unity in both cases.

An Element whose atom is capable of replacing one atom of hydrogen is called a *monad;* when it can replace two of hydrogen, it is termed a *diad;* when three, a *triad;* four, a *tetrad;* five, a *pentad;* and six, a *hexad.*

13. **By Absolute Atomicity** is meant the highest number of bonds (lines of force, or points of attachment) which an element is known to have.

14. **By Active Atomicity** is understood the number of bonds engaged in a compound; the number of bonds not engaged being called **Latent Atomicity.**

15. The name **Simple Radical** is given to the elementary bodies.

16. **A Compound Radical** consists of a group of two or more atoms, which takes the place and performs the functions of an element in a chemical compound. The term is only applied to such groups as are found in numerous chemical compounds. The following is a list of some of the most important compound radicals, with their formulæ:—

Hydroxyl (Ho), Hydrosulphyl (Hs), Ammonium (Am), Ammonoxyl (Amo), Potassoxyl (Ko′), Sodoxyl (Nao′), Zincoxyl (Zno″).

Sc. Ex., 1868, A.—What is meant by the atomicity or quantivalence of an element? 12.

Sc. Ex., 1870, E.—What is meant by the atomicity or equivalence of an element? Give the atomicity of all the non-metallic elements. 12 and 108.

Illustrations of the mode in which the compound radicals enter into combination:—NO_2Ho (nitric acid), NH_4Ho (ammonic hydrate), SO_2Ko_2 (potassic sulphate), $CONao_2$ (sodic carbonate) SO^2Zno'' (zincic sulphate).

17. **An Acid** is a compound containing one or more atoms of hydrogen, which it can exchange for potassium or sodium when one of these metals is presented to it in the form of a hydrate. An acid containing one such atom of hydrogen is said to be *monobasic;* two, *dibasic;* three, *tribasic;* and four, *tetrabasic.*

18. **A Base** is a compound which is converted into a salt by the action of an acid. Bases are of three classes:—1st, metallic oxides; 2nd, metallic hydrates; 3rd, certain compounds of hydrogen with nitrogen, phosphorus, arsenic, antimony, &c., such as ammonia, phosphoretted hydrogen, arsenetted hydrogen, and aniline.

19. **A Salt** is a compound produced by the action of an acid upon a base.

20. **An Oxidising Agent** is a substance which gives oxygen to bodies, the following being the most common oxidisers:—nitric acid and nitrates, chloric acid and chlorates, chlorine in presence of moisture, hypochlorous acid and

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Sc. Ex., 1860, A.—What do you understand by the term "compound radical?" Give some examples of inorganic compound radicals, and write out the constitutional formulæ of a few bodies illustrating the functions of these radicals. 16.

Sc. Ex., May, 1861.—Give a definition of the terms "acid," "base," and "salt." 17, 18 and 19.

Sc. Ex., 1868, A.—What meaning do you attach to the terms "acid," "base," and "salt?" 17, 18 and 19.

hypochlorites, air and oxygen gas, bichromate of potassium, manganic oxide, permanganate of potassium, charcoal and air, the outer blowpipe flame, &c.

21. **A Reducing or De-oxidising Agent** is a substance which removes oxygen from bodies, the following being the most common:—carbon and hydrogen at high temperatures, nascent hydrogen, sulphurous acid and sulphates, sulphuretted hydrogen, hyposulphites, arsenious anhydride, ferrous and stannous salts, potassium and sodium, the inner blowpipe flame, &c.

22. **An Oxide** is a compound of oxygen and any of the other elements; compounds of metals and oxygen being termed *Metallic Oxides.*

23. **An Anhydride** is the residue of an acid from which water has been abstracted.

24. **A Hydrate** is a compound formed by the union of water with a compound.

25. **An Oxacid or Oxy-acid** is an acid containing oxygen.

26. **A Hydracid** is an acid containing no oxygen, and which is formed by the union of hydrogen with some other element.

27. **A Sulph-acid** is one which contains sulphur in the place of oxygen.

28. **By specific weight or specific gravity** is meant the number which expresses the ratio which the weight of a cubic inch of the body bears to the weight of a cubic inch of distilled water at a temperature of 15·5°C.

29. **The Metals** are elements which have great lustre, are good conductors of heat and electricity, and possess the properties of malleability, ductility, tenacity, and fusibility. The non-metallic bodies, or metalloids as they are sometimes called, do not possess these properties.

30. **A Crith** is the name given to the weight of a litre of hydrogen at the normal temperature and pressure. Its weight is ·0896 gramme.

31. **Three different kinds of Notation** are in use for the purpose of representing the atomic constitution of molecules, or the mode in which, as it were, the molecule is built up. These are the glyptic, graphic, and symbolic formulæ.

32. **The Glyptic** mode of representing molecular constitution consists of coloured wooden balls connected by pegs of wood, or short pieces of small brass gas-piping. The balls represent the atoms, and the pegs of wood the bonds or lines of force.

33. **The Graphic Formulæ** are the pictorial representations of glyptic formulæ, in which the atoms are shown by circles, and the bonds by connecting lines.

34. **In Symbolical Formulæ** the atoms are represented by the symbols of the elements.

35. **An Empirical Formula** is one in which the symbols in a formula are placed without any

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Sc. Ex., 1870, E.—What do you understand by the terms "element," "oxide," "metal" and "non-metal?" 2, 22 and 29.

regard being had to the mode in which their bonds are satisfied, *e.g.*, SO_4H_2 (sulphuric acid) and $CaSO_4$ (calcic sulphate).

36. **Constitutional or Rational Formulæ** are the symbolical representatives of the glyptic and graphic Formulæ; they exhibit at the same time the number of atoms and weight of the elements, and also their mode of arrangement in the molecule, *e.g.*, SO_2Ho_2 (sulphuric acid), and SO_2Cao'' (calcic sulphate.)

Sc. Ex., 1870, A.—What are empirical, rational, and constitutional formulæ? Give examples of each. 35, 36.

EXPLANATION

OF SOME OF THE

TERMS USED IN CHEMISTRY.

37. **Allotropic.**—A body having different physical forms; carbon, for instance, occurs as the diamond, graphite or black-lead, and charcoal.

38. **Alkalies.**—Substances such as soda, lime, potash, and ammonia; they have a strong tendency to combine with acids, and form alkaline salts.

39. **Alloy.**—A combination of two or more metals, such as copper and zinc, to form brass. Gold used for coinage is alloyed with copper or silver.

40. **Amalgam.**—A mixture of mercury with any other metal.

41. **Amorphous.**—Without definite form; the opposite of the crystallized form of bodies. Charcoal is amorphous carbon; the diamond is crystallized carbon, as also is graphite.

42. **Ammoniacal Salts.**—Salts formed by the union of any acids with ammonia, or by the union of the radical of a hydrogen acid with ammonium.

43. **Analysis.**—The separation of a compound body either into its proximate or elementary constituents.

44. **Anhydrous.**—Destitute of water.

45. **Anti-septic.**—Possessing the power of preventing putrefaction.

46. **Atmospheres.**—This word is used to express the additional pressure given to fluids. If, for instance, a vessel be filled with carbonic anhydride, and a pressure of 15lbs. upon every square inch of the surface be applied, it is said to be a pressure of one atmosphere; if 30lbs., two atmospheres; if 45lbs., three atmospheres, and so on.

47. **Azote.**—Another name for nitrogen.

48. **Barometer.** — An instrument which shows the variation of the pressure of the atmosphere by the rise and fall of a column of mercury contained in a glass tube.

49. **Borates.**—Salts formed by the union of boracic acid with a base.

50. **Caoutchouc.**—India-rubber

51. **Carbonates.** — Salts formed by the union of carbonic acid with any base.

52. **Caustic.** — Possessing the power of burning.

53. **Centigrade.**—The thermometric scale in which the freezing point is 0° and the boiling point 100°.

54. **Combustion.**—A term generally applied to express the phenomena of the evolution of light

of formation.
ascent at the
compound.

of rendering a

by the union
nitric acid and

Salts.—Salts
is replaced.

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base.

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sulphuric

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whence they had been displaced by external pressure.

65. **Elastic Fluids.**—A name given to vapours and gases.

66. **Evaporation.**—The conversion of fluids into vapour by heat.

67. **Eudiometer.**—An instrument used for investigating the composition of different gases, and the purity of atmospheric air.

68. **Fahrenheit.**—A thermometric scale, the boiling point of which is 212°, and the freezing point 32°.

69. **Filtration.**—A process for separating liquids in a state of purity from solid bodies.

70. **Fusibility.**—A property by which a body may be fused or melted.

71. **Gaseous.**—Having the nature and properties of a gas.

72. **Gasometer.**—An apparatus for collecting and preserving gas.

73. **Haloid.**—A term for iodine, chlorine, bromine, and fluorine, which produce salts by their union with the metals, as chloride of sodium.

74. **Homogeneous.**—Alike in nature and properties.

75. **Hydrometer.**—An instrument for determining the specific gravity of fluids.

76. **Malleability.**—A property by which metals may be extended into thin plates or leaves by hammeri~

77. **Nascent.**—In the moment of formation. A gas, for instance, is said to be nascent at the moment of its liberation from some compound.

78. **Neutralize.**—The act of rendering a solution neither acid nor alkaline.

79. **Nitrates.**—Salts formed by the union of nitric acid with a base, or with nitric acid and a basic radical.

80. **Normal or Neutral Salts.**—Salts in which the whole of the hydrogen is replaced.

81. **Phosphates.** — Salts formed by the union of phosphoric acid with any base.

82. **Precipitate.**—The substance dissolved in a fluid, which falls to the bottom on the addition of a re-agent, and is left on the filter in the act of filtration.

83. **Sublimation.** — A process by which volatile bodies are condensed by cold into a solid form. The soot of chimneys is a familiar instance of this kind.

84. **Sulphates.**—Salts formed by the union of sulphuric acid with any base, or with sulphuric acid and a basic radical.

85. **Synthesis.**—The forming of a compound by the union of its elements, as contrasted with analysis.

86. **Tenacity.** — A property by which a body resists being torn asunder.

MODES OF CHEMICAL ACTION.

(FRANKLAND.)

Matter undergoes chemical change in five different ways, viz.:—

87. *First.*—**By direct combination** of elements or compounds with each other; as when powdered antimony is burned in chlorine.

88. *Second.*—**By the displacement** of one element or compound radical in a body by another element or compound radical; as in the preparation of hydrogen by acting on sulphuric acid with zinc.

89. *Third.*—**By a mutual exchange** of elements or compound radicals in two or more bodies; as in the production of a salt by an acid acting on a base, for example, sulphuric acid acting on the base, sodic oxide, produces the salt, sodic sulphate.

90. *Fourth.*—**By the re-arrangement** of the elements or compound radicals already contained in a body; as, perhaps, in the preparation of ozone. There are no good illustrations of this mode in inorganic chemistry.

91. *Fifth.*—**By the resolution** of a compound into its elements, or into two or more less complex compounds; as in the preparation of oxygen from mercuric oxide and potassic chlorate, and the decomposition of water and hydrochloric acid by the galvanic current.

LAWS OF VAPOUR VOLUME.

92. **Ampere's Law.**—All gases and vapours contain the same number of molecules within the same volume.

93. **Boyle and Marriotte's Law.**—The volume of a gas is inversely, and its density directly as the pressure which it sustains, if the temperature remain the same.

94. **The Co-efficient of Expansion of Gases by heat** under all pressures is $\frac{1}{273}$ of the volume of the gas at 0° Centigrade for each increase of one degree.

95. **The densities of almost all Elementary Gases** are identical with their atomic weights; that of hydrogen being taken as unity.

96. **The densities of almost all Compound Gases** are half their atomic weights.

97. **Standard or Normal Temperature.**—0° Centigrade.

98. **Standard or Normal Pressure.** 760m.m. Bar.

99. **Standard Volume, Hoffman's.** One litre of hydrogen at 0°C and 760m.m. Bar. weighs ·0896 gramme, and this weight is called a crith.

100. **Standard Volume, Williamson's** One gramme of hydrogen at 0°C and 760m.m. Bar. measures 11·19 or very nearly 11·2 litres.

WEIGHTS AND MEASURES.

101 WEIGHTS.

1 Gramme	=	the unit (15·434 grains)
10 Grammes	=	1 decagramme
100 ,,	=	1 hectogramme
1000 ,,	=	1 kilogramme
·1 or $\frac{1}{10}$ Gramme	=	1 decigramme
·01 or $\frac{1}{100}$,,	=	1 centigramme
·001 or $\frac{1}{1000}$,,	=	1 milligramme

102 LINEAR MEASURE.

1 Metre	=	the unit (39·37 inches)
10 Metres	=	1 decametre
100 ,,	=	1 hectometre
1000 ,,	=	1 kilometre
·1 or $\frac{1}{10}$ Metre	=	1 decimetre
·01 or $\frac{1}{100}$,,	=	1 centimetre
·001 or $\frac{1}{1000}$,,	=	1 millimetre (m.m.)

103 MEASURE OF CAPACITY.

1 Litre = the unit (61·027 cu. in. or 1·76 pints)

10 Litres	=	1 decalitre
100 ,,	=	1 hectolitre
1000 ,,	=	1 kilolitre (1 cubic metre)
·1 or $\frac{1}{10}$ Litre	=	1 decilitre
·01 or $\frac{1}{100}$,,	=	1 centilitre
·001 or $\frac{1}{1000}$,,	=	1 millilitre (1 cubic centimetre)

104. 1 cubic centimetre of distilled water, taken at 4°C, its point of greatest density, weighs one gramme.

1 litre of distilled water, taken at 4°C., weighs 1000 grammes.

1 litre of hydrogen at 0°C and 760m.m. Bar. weighs 1 crith.

1 crith = ·0896 gramme.

TABLE OF ELEMENTS.

105 NON-METALLIC ELEMENTS.

Names.	Symbols.	Atomic Weights.	Specific Gravities.
Hydrogen ...	H	1	1
Oxygen	O	16	16
Nitrogen	N	14	14
Chlorine	Cl	35·5	35·5
Bromine	Br	80	2·97
Iodine	I	127	4·948
Fluorine	F	19	......
Carbon	C	12	3·5
Boron	B	11	2·68
Silicon.........	Si	28·5	2·49
Phosphorus...	P	31	1·77
Sulphur	S	32	2·07
Selenium......	Se	79	4·28
Tellurium ...	Te	129	6·25

Sc, Ex., 1868, E.—Give the names and symbols of the non-metallic elements. 105.

MOST IMPORTANT METALLIC ELEMENTS.

Names.	Symbols.	Atomic Weights.	Specific Gravities.
Aluminium	Al	27·5	2·60
Antimony (Stibium)	Sb	122	6·70
Arsenic	As	75	5·88
Barium	Ba	137	4 to 5
Bismuth	Bi	210	9·82
Calcium	Ca	40	1·6
Chromium	Cr	52·5	5·9
Cobalt	Co	58·8	8·54
Copper (Cuprum) ...	Cu	63·5	8·96
Gold (Aurum)	Au	196·7	19·5
Iron (Ferrum)	Fe	56	7·079
Lead (Plumbum) ...	Pb	207	11·45
Magnesium	Mg	24	1·70
Manganese	Mn	55	6·85
Mercury (Hydrargyrum)	Hg	200	13·59
Nickel	Ni	58·8	8·80
Platinum	Pt	197·5	21·50
Potassium (Kalium)	K	39·1	0·865
Silver (Argentum)...	Ag	108	10·47
Sodium (Natrium) ...	Na	23	0·972
Strontium	Sr	87·5	2·5
Tin (Stannum)	Sn	118	7·29
Zinc	Zn	65	7·1 to 7·86

107 RARER METALLIC ELEMENTS.

Names.	Sym-bols.	Atomic Weights.	Specific Gravities.
Cadmium	Cd	112	8·7
Caesium...............	Cs	133	......
Cerium	Ce	92	......
Didymium............	D	96	......
Erbium	E	112·6	......
Glucinum	Gl	9·3	3
Indium	In	74	......
Iridium	Ir	198	16
Lanthanum	La	92	......
Lithium	Li	7	......
Molybdenum.........	Mo	96	8·6
Niobium	Nb	94	......
Osmium...............	Os	199·2	10
Palladium	Pd	106·6	11.3 to 11·8
Rhodium	Rh	104·4	11
Rubidium	Rb	85·4	......
Ruthenium	Ru	104·4	8·6
Tantalum	Ta	172	......
Thallium	Tl	204	......
Thorium	Th	115·7	......
Titanium	Ti	50	5·3
Tungsten (Wolfram)	W	184	17·6
Uranium	U	120	......
Vanadium	V	137	......
Yttrium	Y	61·6	......
Zirconium............	Zr	89·6	......

108. **Table of the most Common Elements,** classified according to their atomicities, with their symbols and atomic weights. The letters *a*, *b*, *c*, *d* show a further subdivision into sections or families. The elements are classified under their highest known atomicities. An artiad never becomes a perissad, nor a perissad an artiad, but the pentads are frequenly triads or monads, and the hexads, tetrads or diads. The elements printed in italics are non-metallic, the rest are metals. The elements marked with * are chlorus, the rest are basylous.

PERISSADS (Atomicity Odd).

Monads (1)			Triads (3)			Pentads (5)		
a			*a*			*a*		
Hydrogen	H	1	*Boron*	B	11	*Nitrogen*	N	14
b			*b*			*Phosphorus*	P	31
**Chlorine*	Cl	35·5	Gold	Au	196·7	Arsenic	As	75
**Bromine*	Br	80				Antimony	Sb	122
**Iodine*	I	127				Bismuth	Bi	210
**Fluorine*	F	19						
c								
Potassium	K	39·1						
Sodium	Na	23						
Lithium	Li	7						
d								
Silver	Ag	108						

ARTIADS (Atomicity Even).

Diads (2)			Tetrads (4)			Hexads (6)		
a			*a*			*a*		
**Oxygen*	O	16	*Carbon*	C	12	**Sulphur*	S	32
b			*Silicon*	Si	28·5	**Selenium*	Se	79
Barium	Ba	137	Tin	Sn	118	*b*		
Strontium	Sr	87·5	Titanium	Ti	50	Chromium	Cr	52·5
Calcium	Ca	40	*b*			Manganese	Mn	55
Magnsm.	Mg	24	Almnium.	Al	27·5	Iron	Fe	56
Zinc	Zn	65	*c*			Cobalt	Co	58·8
c			Platinum	Pt	197·5	Nickel	Ni	58·8
Cadmium	Cd	112	Palladium	Pd	106·5	Uranium	U	120
Mercury	Hg	200	*d*					
Copper	Cu	63 5	Lead	Pb	207			

Sc. Ex., 1868, A.—Classify 20 of the most important elements according to their atomicity. 108.

Sc. Ex., 1869, E.—What is the atomicity or equivalence of the following elements:—chlorine, calcium, magnesium, silver, tin, lead, and arsenic? 108.

Sc. Ex., 1869, E.—What is meant by the atomicity or equivalence of an element? Give the atomicity of all the non-metallic elements. 12 and 108.

109 CONSTITUTIONAL FORMULÆ OF SOME OF THE MOST COMMON SALTS.

These formulæ are arranged so that the element represented by the left-hand symbol engages all the active atomicities of the other elements and compound radicals following upon the same line, and also all the spare atomicities of any element whose symbol is placed immediately above or below it. M represents the metal, compound radical, or basylous element. Mo, in the column of monads, represents a monad compound radical, such as Ko, Nao, &c. Mo″, in the diad column, represents a diad compound radical, such as Zno″ (ZnO_2), Feo″ (FeO_2). In the formulæ of acids, Ho represents the monad compound radical hydroxyl. Salts of pentads and hexads are rare.

Symbol of Acid.	Name of Acid.	Name of Salts.	Of Monads	Of Diads.	Of Triads.	Of Tetrads.
	Monobasic Acids.					
$\begin{cases} \text{OBr} \\ \text{OHo} \end{cases}$	Bromic	Bromates	$\begin{cases} \text{OBr} \\ \text{OMo} \end{cases}$	$\begin{cases} \text{OBr} \\ \text{O} \\ \text{Mo}'' \\ \text{O} \\ \text{OBr} \end{cases}$		

Symbol of Acid.	Name of Acid.	Name of Salts.	Of Monads	Of Diads.	Of Triads	Of Tetrads.
	Monobasic Acids *continued.*					
HBr	Hydrobromic	Bromides	MBr	$\mathbf{M}Br_2$...	$\mathbf{M}Br_3$	$\mathbf{M}Br_4$ $'\mathbf{M}'''_2Br_6$
$\left\{\begin{matrix}OCl\\OHo\end{matrix}\right.$	Chloric	Chlorates	$\left\{\begin{matrix}OCl\\OMo\end{matrix}\right.$	$\left\{\begin{matrix}OCl\\O\\Mo''\\O\\OCl\end{matrix}\right.$		
HCl	Hydrochloric	Chlorides	MCl	$\mathbf{M}Cl_2$	$\mathbf{M}Cl_3$	$\mathbf{M}Cl_4$ $'\mathbf{M}'''_2Cl_6$
$OClHo$	Chlorous	Chlorites	$OClMo$	$\left\{\begin{matrix}OCl\\Mo''\\OCl\end{matrix}\right.$		
HF	Hydrofluoric	Fluorides	MF	$\mathbf{M}F_2$	$\mathbf{M}F_3$	$\mathbf{M}F_4$ $'\mathbf{M}'''_2F_6$
$ClHo$	Hypochlorous ...	Hypochlorites ...	$ClMo$	$MoCl_2$		

Symbol of Acid.	Name of Acid.	Name of Salts.	Of Monads	Of Diads.	Of Triads.	Of Tetrads.
	Monobasic Acids *continued.*					
$\left\{\begin{matrix}OI\\OHo\end{matrix}\right.$	Iodic	Iodates	$\left\{\begin{matrix}OI\\OMo\end{matrix}\right.$	$\left\{\begin{matrix}OI\\O\\Mo''\\O\\OI\end{matrix}\right.$		
HI	Hydriodic	Iodides	MI	MI_2	MI_3	MI_4 $'M'''_2I_6$
NO_2Ho	Nitric	Nitrates	NO_2Mo	$\left\{\begin{matrix}NO_2\\Mo''\\NO_2\end{matrix}\right.$	N_3O_6Mo''	$N_6O_{12}('M'''_2O_6)^{vi}$
NOHo	Nitrous	Nitrites	NOMo	$\left\{\begin{matrix}NO\\Mo''\\NO\end{matrix}\right.$		

Symbol of Acid.	Name of Acid.	Name of Salts.	Of Monads	Of Diads.	Of Tetrads.
$\left\{\begin{matrix}OCl\\O\\OHo\end{matrix}\right.$	Perchloric	Perchlorates	$\left\{\begin{matrix}OCl\\O\\OMo\end{matrix}\right.$	$\left\{\begin{matrix}OCl\\O\\O\\Mo''\\O\\O\\OCl\end{matrix}\right.$	
	Dibasic Acids.				
$COHo_2$	Carbonic	Carbonates.........	$COMo_2$	$COMo''$	
CrO_2Ho_2	Chromic	Chromates	CrO_2Mo_2	CrO_2Mo''	
$SSOHo_2$	Hyposulphurous...	Hyposulphites ...	$SSOMo_2$	$SSOMo''$	
$\left\{\begin{matrix}COHo\\COHo\end{matrix}\right.$	Oxalic..............	Oxalates............	$\left\{\begin{matrix}COMo\\COMo\end{matrix}\right.$	$\left\{\begin{matrix}CO\\CO\end{matrix}\right. Mo''$	
SO_2Ho^2	Sulphuric	Sulphates	SO_2Mo_2	SO_2Mo''	$\left.\begin{matrix}SO_2\\SO_2\\SO_2\end{matrix}\right) \text{-}('M'''_2O_6)^{vi}$

Symbol of Acid.	Name of Acid.	Name of Salts.	Of Monads	Of Diads.	Of Tetrads.
	Dibasic Acids *continued.*				
SH_2	Hydrosulphuric …	Sulphides ………	SM_2	SM	$\left\{\begin{matrix}'M'''S \\ 'M'''S\end{matrix}\right. S$
$SOHo_2$	Sulphurous ……	Sulphites ………	$SOMo_2$	$SOMo''$	
	Tribasic Acids.				
$AsOHo_3$	Arsenic …………	Arsenates ………	$AsOMo_3$	$\left\{\begin{matrix}AsOMo'' \\ Mo'' \\ AsOMo''\end{matrix}\right.$	
$AsHo_3$	Arsenious ………	Arsenites ………	$AsMo_3$	$\left\{\begin{matrix}AsMo'' \\ Mo'' \\ AsMo''\end{matrix}\right.$	
BHo_3	Boric ……………	Borates …………	BMo_3		
$POHo_3$	Phosphoric …… (Orthophosphoric)	Phosphates………	$POMO_3$	$P_2O_2Mo''_3$	$P_4O('M'''_2O_6)^{VI}_3$
*PO_2Ho	Phosphoric …… (Metaphosphoric)	Metaphosphates…	PO_2Mo	P_2O_4Mo''	

Symbol of Acid.	Name of Acid.	Name of Salts.	Of Monads	Of Diads.	Of Tetrads.
	Tribasic Acids *continued.*				
‡$P_2O_3Ho_4$	Phosphoric ...... (Pyrophosphoric)	Pyrophosphates ...	$P_2O_3Mo_4$	$P_2O_3Mo''_2$	
*POH_2Ho	Hypophosphorous	Hypophosphites...	POH_2Mo	$\left\{\begin{matrix}POH_2\\Mo''\\POH_2\end{matrix}\right.$	
†$POHHo_2$	Phosphorous	Phosphites	$POHMo_2$	$POHMo''$	
	Tetrabasic Acids.				
$SiHo_4$	Silicic	Silicates	$SiMo_4$	$SiMo''_2$	$Si_3O_3('M'''_2O_6)^{vi}$

BASES	Of Monads.	Of Diads.	Of Triads.	Of Tetrads.
Oxides............	M_2O	MO	M_2O_3	MO_2
Hydrates.........	MHO	MHo_2		MHo_4
				$'M_2'''Ho_6$

* Monobasic. † Dibasic. ‡ Tetrabasic.

LIST OF COMPOUNDS.

110. In binary compounds, the name of the positive or basylous element, or some abbreviated form of it, or of its Latin name, is made to terminate in "ic," and is placed first; and the negative or chlorous element, or its abbreviation, comes after it with the termination "ide." The positive element frequently forms more than one compound with the same negative element; and when this is the case, the compound which contains the largest proportion of the negative element has the terminal "ic" to the positive constituent, and that which contains the smaller amount, has the terminal "ous." Where there is more of the negative constituent than the one represented by "ic," the prefix "per" is used, as in calcic peroxide, CaO_2; and where there is less of the the negative element than that represented by "ous," the prefix "hypo" is used, as in hypochlorous acid ClHo.

The names given in brackets are other names given to the substances; and the student is recommended to get the names and formulæ of these compounds well up. It must also be remembered that the names of many of the compounds may be changed, as in the following examples:—sodic chloride (chloride of sodium), argentic oxide (oxide of silver), potassic sulphate (sulphate of potash), ammonic nitrate (nitrate of ammonia).

111. OXIDES.

Aluminic oxide.........Al_2O_3

Argentic oxide ....OAg_2

Baric oxide ....BaO (baryta)

Baric peroxide ....BaO_2 or $\begin{matrix}O\\O\end{matrix}\Big\{Ba''$

Calcic oxide ....CaO(lime, quicklime)

Calcic peroxide.........CaO_2

Carbonic oxide ....CO

Chloric peroxide ......O_4Cl_2 or $\begin{cases}OCl\\O\\O\\OCl\end{cases}$

Cuprous oxide ....Cu_2O

Cupric ,, ...CuO

Ferrous ,, ...FeO

Ferric ,, ...Fe_2O_3

Hydric ,, ...OH_2 (water)

Hydric peroxide ......H_2O_2 or Ho (hydroxyl)

Magnesic oxide.........MgO (magnesia)

Magnetic ,, ...Fe_3O_4 (loadstone, magnetic iron ore)

Manganous oxide ......MnO

Manganic ,, ...MnO_2

Mercurous ,, ...Hg_2O

Mercuric ,, ...HgO (red precipitate)

Nitrous ,, ...ON_2 (laughing gas)

Nitric ,, ...N_2O_2

Nitric peroxide ....$N\ O_4$

Potassic-zincic oxide ...$ZnKo_2$

Sodic oxide ....ONa_2 (soda)

Stannous oxide ....SnO

Stannic ,, ...SnO_2

Strontic ,, ...SrO (strontia)

112 ACIDS.

Boric acid (boracic)............BHo_3
Carbonic acid ....$COHo_2$
Hypochlorous acid ....ClHo
Chlorous ,, ...OClHo
Chloric acid ...O_2ClHo or $\begin{cases} OCl \\ OHo \end{cases}$ or Ho_3Cl
Perchloric acid O_3ClHo or $\begin{cases} OCl \\ O \\ OHo \end{cases}$ or Ho_4Cl
Hydrochloric acid...............HCl
Hydrobromic ,, ...HBr
Hydriodic ,, ...HI
Hydrofluoric ,, ...HF
Hydrosulphuric,, (sulphuretted hydrogen) SH_2
Nitrous ,, ...NoHo
Nitric acid (aquafortis).........NO_2Ho
Oxalic acid ....$\begin{cases} COHo \\ COHo \end{cases}$
Hypophosphoric acid ....POH_2Ho
Phosphorous acid ....$POHHo_2$
Phosphoric (orthophosphoric) acid $POHo_3$
Metaphosphoric acid ....PO_2Ho
Pyrophosphoric acid ....$P_2O_3Ho_4$
Hyposulphurous acid............$SSOHo_2$
Sulphurous acid..................$SOHo_2$
Sulphuric acid ....SO_2Ho^2

118 ANHYDRIDES.

Arsenious anhydride.............As^2O^3
Arsenic ,, ...As_2O_5
Boric ,, ...B^2O_3
Carbonic ,, ...CO_2
Hypochlorous ,, ...OCl_2

ANHYDRIDES (continued).

Chlorous anhydride	O^8Cl^2 or $\left\{\begin{array}{l}OCl\\O\\OCl\end{array}\right.$
Nitrous anhydride	N_2O_3
Nitric anhydride	N_2O_5
Phosphorous anhydride	P_2O_3
Phosphoric ,,	P_2O_5
Silicic anhydride (silica)	SiO_2
Sulphurous anhydride	SO_2
Sulphuric ,,	SO_3
Sulpharsenic ,,	As_2S_5

114 CHLORIDES.

Aluminic chloride	Al_2Cl_6
Ammonic ,, (salammoniac)	NH_4Cl or AmCl
Antimonious chloride	$SbCl_3$
Antimonic ,,	$SbCl_5$
Argentic ,,	AgCl
Auric ,,	$AuCl_3$
Baric ,,	$BaCl_2$
Bismuthous ,,	$BiCl_3$
Boric ,,	BCl_3
Calcic ,,	$CaCl_2$
Ferrous ,,	$FeCl_2$
Ferric ,,	Fe_2Cl_6
Hydric chloride (hydrochloric acid)	HCl
Manganous chloride	$MnCl_2$
Manganic ,,	$MnCl_4$
Mercurous ,, (calomel)	Hg_2Cl_2
Mercuric ,, (corsve. sublimate)	$HgCl_2$
Phosphoric ,,	PCl_5
Potassic ,,	KCl

CHLORIDES (continued).

Sodic ,, (common salt) $NaCl$
Stannous ,, ... $SnCl_2$
Stannic ,, ... $SnCl_4$
Zincic ,, ... $ZnCl_2$

115 SULPHIDES.

Ammonic sulphide..................... SAm_2
Hydric-ammonic sulphide . ... $SHAm$
Ammonic disulphide .... S_2Am_2
Antimonious sulphide .... Sb_2S_3
Antimonic ,, ... Sb_2S_5
Baric ,, ... BaS
Bismuthous ,, ... Bi_2S_3
Calcic disulphide .... CaS_2
Carbonic disulphide .... CS_2
Cuprous sulphide .... Cu_2S
Cupric sulphide (indigo or blue copper) CuS
Ferrous ,, ... FeS
Ferric disulphide .... FeS_2
Mercuric sulphide (vermilion).......... HgS
Persulphide of hydrogen (hydrosulphyl) S_2H_2 or Hs^2
Plumbic sulphide (galena) .... PbS
Potassic ,, ... SK_2
Sodic ,, ... SNa_2

116 SULPHATES.

Ammonic sulphate SO_2Amo_2 or $SO_2(NH_4O)_2$
Argentic ,, ... SO^2Ago_2
Baric ,, ... SO_2Bao''
Calcic ,, (gypsum)............ SO^2Cao''

SULPHATES (continued).

Chromic sulphate.................... $S_2O_6(Cr_2O_6)^{vi}$
Cupric ,, (blue vitriol)... SO_2Cuo''
Ferrous ,, (green vitriol, copperas) SO_2Feo''
Ferric sulphate...................... $S_2O_6(Fe_2O_6)^{vi}$
Magnesic ,, (Epsom salts) ... SO_2Mgo''
Manganous .... SO_2Mno''
Potassic ,, ... SO_2Ko_2
Hydric-potassic sulphate .... SO_2KoHo
Sodic sulphate (Glauber's salts) SO_2Nao_2
Hydric-sodic sulphate .... SO_2HoNao
Strontic sulphate (celestine) ...... SO_2Sro''
Zincic ,, (white vitriol)... SO_2Zno''

117 HYDRATES.

Ammonic hydrate ....NH_4Ho or $AmHo$
Baric hydrate (baryta water) $BaHo_2$
Calcic ,, (slaked lime) $CaHo_2$
Potassic ,, (caustic potash) OKH or KHo
Sodic ,, (caustic soda) $ONaH$ or $NaHo$

118 CARBONATES.

Ammonic carbonate .... $COAmo_2$
Hydric-ammonic carbonate (bi-carbonate of ammonia) .... $COHAmo$
Baric carbonate........................ $COBao''$
Calcic ,, (chalk, marble) ...$COCao''$
Potassic ,, ... $COKo_2$
Hydric-potassic carbonate .... $COHoKo$
Sodic carbonate (soda crystals)...... $CONao_2$
Hydric-sodic carbonate .... $COHoNao$
Sodic-sulphocarbonate .... $CSNas_2$
Zincic carbonate (calamine) .... $COZno''$

119 NITRATES.

Ammonic nitrate	....	NO_2Amo
Argentic ,,	....	NO_2Ago
Cupric ,,	....	N_2O_4Cuo''
Plumbic ,,	....	N_2O_4Pbo''
Potassic ,,	(nitre, saltpetre)	NO_2Ko
Sodic ,,	(Chili saltpetre)...	NO_2Nao

120 CHLORATES.

Baric chlorate ....O_4Cl_2Bao'' or $\begin{cases} OCl \\ O \\ Bao'' \\ O \\ OCl \end{cases}$

Calcic chlorate ....O_4Cl_2Cao'' or $\begin{cases} OCl \\ O \\ Cao'' \\ O \\ OCl \end{cases}$

Potassic chlorate ....O_2ClKo or $\begin{cases} OCl \\ OKo \end{cases}$

Potassic perchlorate ... O_3ClKo or $\begin{cases} OCl \\ O \\ OKo \end{cases}$

121 MISCELLANEOUS COMPOUNDS.

Phosphoretted hydrogen (phosphine)		PH_3
Arseniuretted ,,	....	AsH_3
Ammonia (nitrine, spirits of hartshorn)		NH_3
Marsh gas	....	CH_4
Borax (sodic borate)	....	$B_4O_5Nao_2$
Ammonium	....	NH_4

MISCELLANEOUS COMPOUNDS (continued).

Ammonic nitrite ....$N'''O$ $(N^vH_4O)'$
Potassic ,, ...$NOKo$
Calcic chloro-hypochlorite (bleaching powder and chloride of lime).........$Ca(OCl)Cl$
Calcic sulphite ....$SOCao''$
Ferrous iodide ....FeI_2
Mercuric ,, ...HgI_2
Di-mercuric-ammonic iodide...NHg_2I
Potassic iodide ....KI

Mercuric oxy-chloride ...Hg_2OCl_2 or $\begin{cases} HgCl \\ O \\ HgCl \end{cases}$

QUESTIONS ON THE ELEMENTS & COMPOUNDS WITH ANSWERS

Sc. Ex., 1870, E.—Give the names of the substances denoted by the following chemical formulæ:—

OH^2	HCl	Cl_2
N_2O^5	B_2O_3	HO_3Cl
O_3	SO_2	NH_3

Answer—

Water	Hydrochloric acid	Chlorine (molecule)
Nitric anhydride	Boric anhydride	Chloric acid
Ozone	Sulphurous anhde.	Ammonia

Sc. Ex., 1870, E.—Give the formulæ of the following substances:—

Water	Ozone	Sal-ammoniac
Perchloric acid	Hydroxyl	Boric anhydride
Sulphuric acid	Carbonic anhde.	Hypochlorous acid

Answer—

OH_2	O_3	NH^4Cl
HO_4Cl	Ho	B_2O_3
SO_2Ho_2	CO_2	$ClHo$

QUESTIONS (continued).

Sc. Ex., 1870, E.—Classify the following substances into elements and compounds:—

Epsom salts	Calomel	Iodine
Copper	Nitre	Lead
Bronze	Tin	Brass
Chalk	Graphite	Diamond

Answer—

ELEMENTS.		COMPOUNDS.	
Copper	Iodine	Epsom salts	Calomel
Tin	Lead	Bronze	Nitre
Graphite (carb.)	Diamond (carb.)	Chalk	Brass

Sc. Ex., 1869, E.—Classify the following substances into elements and compounds:—

Common salt	Mercury	Oxygen
Iron	Sulphur	Laughing gas
Gypsum	Ozone	Ammonia
Water	Corrosive sublimate	Lime

Answer—

ELEMENTS.		COMPOUNDS.	
Iron	Ozone	Common salt	Laughing gas
Mercury	Oxygen	Gypsum	Ammonia
Sulphur		Water	Lime
		Corosve. sublimate	

Sc. Ex., 1869, E.—Give the symbolic chemical formulæ of the following substances:—

Hydrochloric acid	Carbonate of soda	Stannous oxide
Sulphate of soda	Sulphate of copper	Calomel
Nitrate of potash	Stannic chloride	Vermilion

Answer—

HCl	$CONao_2$	SnO
SO_2Nao_2	SO_2Cuo''	Hg_2Cl_2
NO^2Ko	$SnCl^4$	HgS

HYDROGEN.

122. Symbol, H. Atomic weight and specific gravity, 1. Molecular weight, 2. 1 litre weighs 1 crith. Atomicity, I.

Discovered by Cavendish in 1777.

123. **Occurrence in Nature.**—Hydrogen is found in a state of combination in nearly all animal and vegetable substances, and also in many minerals. Is also met with in a free state in certain volcanic gases.

124. **Preparation.** — (1) By passing a small piece of sodium or potassium into an inverted cylinder or tube filled with water, and standing on the pneumatic trough :—

$$\underset{\text{Sodium}}{Na_2} + \underset{\text{Water}}{2OH_2} = \underset{\text{Sodic hydrate}}{2ONaH} + \underset{\text{Hydrogen}}{H_2}$$

Only half the hydrogen of the portion of water acted on is displaced by the sodium.

Sc. Ex., 1861.—Describe a process by which hydrogen, and one by which oxygen may be prepared from water. 124 and 135. (4).

Sc. Ex., 1862.—Describe a chemical process by which hydrogen, and one by which oxygen may be prepared from water. 124 and 135 (4).

Sc. Ex., 1862.—What methods are generally employed for the preparation of hydrogen ? 124.

Sc. Ex., 1868, A.—Describe the chief properties of oxygen, hydrogen, and nitrogen, and state how you would prepare these bodies in a state of purity. 125, 124, 136, 135, 175, and 174.

(2). By adding sulphuric acid, diluted with four or five times its bulk of water, to zinc clippings:—

$$\underset{}{Zn} + \underset{\text{Sulphuric acid}}{SO_2Ho_2} = \underset{\text{Zincic sulphate}}{SO_2Zno''} + H_2$$

(3.) By passing steam through an iron tube filled with nails or iron borings, and raised to a red heat:—

$$3Fe + 4OH_2 = \underset{\text{Magnetic oxide}}{Fe_3o_4} + 4H_2$$

(4.) By the electric decomposition (electrolysis) of water:—

$$2OH_2 = O_2 + 2H_2$$

(See method (4) of preparing oxygen, page 47)

(5.) By boiling zinc in a solution of potassic or sodic hydrate:—

$$\underset{\substack{\text{Potassic hydrate}\\ \text{(caustic potash)}}}{2OKH} + Zn = \underset{\substack{\text{Potassic-}\\ \text{zincic oxide}}}{ZnKo} + H_2$$

125. **Properties.** — Permanently gaseous, without colour, taste, or smell. It is the lightest substance known; has a great affinity for oxygen, and forms with that gas an explosive mixture which detonates violently on a light being applied to it. It is combustible, but not a supporter of combustion. Nascent hydrogen, that is, hydrogen at the moment of its liberation from a compound,

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Sc. Ex., 1869, E.—You have given to you zinc, sulphuric acid, caustic potash, and water, and are required to prepare hydrogen from these materials by two distinct processes; state how you would proceed, and show by an equation the chemical change in each case. 124 (2) and (5).

is a very powerful reducing agent. The oxy-hydrogen blowpipe flame consists of two volumes of hydrogen and one of oxygen.

CHLORINE.

126. Symbol, Cl. Atomic weight and sp.gr., 35·5. Molecular weight, 71. 1 litre weighs 35·5 criths. Atomicity, I.

Discovered by Scheele in 1774.

127. **Occurrence in Nature.**—Is found combined with metals forming chlorides, sodic chloride (common salt, NaCl) being the most common. In combination with hydrogen as hydrochloric acid, HCl, it is found among the gases evolved from volcanoes. It does not occur in a free state.

128. **Preparation.**—(1) By heating in a retort or flask strong hydrochloric acid and manganic oxide (peroxide of manganese), well mixed together. As cold water absorbs more than twice its volume of this gas, it should be collected over warm water, or by displacement. The reaction is :—

$$MnO_2 + 4HCl = \underset{\text{Manganic chloride}}{MnCl_4} + 2OH_2$$

The heat decomposes the manganic chloride thus :

$$Mn^{iv}Cl_4 = \underset{\text{Manganous chloride}}{Mn''Cl_2} + Cl_2$$

(2). By gently heating in a flask a mixture of common salt, sulphuric acid, and manganic oxide :—

$$MnO_2 + 2NaCl + 2SO_2Ho_2 = SO_2Mno'' + SO_2Nao_2 + 2OH_2 + Cl_2$$

Sodic chloride — Manganous sulphate — Sodic sulphate

129. **Properties.**—Chlorine is a yellowish-green gas, having a strong suffocating odour, resembling seaweed. When present in large quantities it acts as a violent irritant, producing inflammation of the mucous membrane. It is reduced to a heavy yellow liquid when submitted to a pressure of five atmospheres. Chlorine has great affinity for hydrogen, and but little for oxygen. Many componnds of hydrogen are decomposed by chlorine. A mixture of equal volumes of chlorine and hydrogen explode with great violence on exposure to sunlight, or a lighted taper, producing hydrochloric acid. As moist chlorine destroys organic colouring matters, it is largely used for bleaching purposes in the cotton, linen, and paper manufactures. It is also employed as a disinfectant and deodorant.

HYDROCHLORIC ACID.

180. Symbol, HCl. Molecular weight, 36·5. 1 litre weighs 18·25 criths.

Discovered in 1650, and .called spirit of salt, muriatic acid.

Sc. Ex., 1862.—How is chlorine prepared? 128.

Sc. Ex., 1869, E.—If a mixture of manganic oxide (peroxide of manganese) and hydrochloric acid be heated, what chemical change takes place? Give the name and properties of the gas which is evolved. 128 and 129.

131. **Preparation.** — (1.) By exploding equal volumes of chlorine and hydrogen; no alteration of volume taking place:—

$$H_2 + Cl_2 = 2HCl$$

(2.) By heating in a flask a mixture of common salt, a little water, and sulphuric acid. It must be collected by displacement, or over mercury. The reaction in the flask is:—

$$NaCl + SO_2Ho_2 = HCl + \underset{\text{Hydric-sodic sulphate}}{SO_2HoNao}$$

When great heat is employed, which cannot be done in a glass vessel, the reaction is as follows:

$$2NaCl + SO_2Ho_2 = 2HCl + \underset{\text{Sodic sulphate}}{SO_2Nao_2}$$

132. **Properties.**—It is a colourless gas, having a sharp acid odour, and fumes on exposure to air. Is very soluble in water. At a temperature of 15°C. water absorbs 458 times its bulk of this gas. It is liquefied under a pressure of 40 atmospheres; is largely used as a solvent for tin for the use of the dyer and calico printer; and it is a most important reagent. That this gas contains equal volumes of hydrogen and chlorine may be proved as follows:—

(1.) *By Synthesis.*—One volume of hydrogen, and one volume of chlorine exploded, yield two volumes of hydrochloric acid.

Sc. Ex., 1862.—How is hydrochloric acid prepared? 131.

Sc. Ex., 1870, E.—How would y[illegible] [illegible]ntally that hydrochloric acid consists of [illegible] [illegible]ine? 132. (1) and (3).

(2.) *By Analysis*—By causing metallic potassium to be burnt in a volume of hydrochloric acid; the gas is reduced to one-half its bulk, the residue being hydrogen.

(3.) When a solution of hydrochloric acid is decomposed by the galvanic current it yields, after some time has elapsed, equal volumes of hydrogen and chlorine.

Aqua regia, a very powerful solvent, is a mixture of hydrochloric and nitric acid.

OXYGEN.

133. Symbol, O. Atomic weight and sp.gr., 16. Molecular weight, 32. 1 litre weighs 16 criths. Atomicity, II.

Priestley discovered oxygen in 1774, and called it **dephlogisticated air.** It was called **empyreal air** and **vital air** by Scheele, a Swedish chemist, who discovered it about the same time. Lavoisier gave it the name oxygen.

134. **Occurrence in Nature.**—It exists in the free state in the atmosphere, of which it constitutes about one-fifth by bulk. It forms, in combination with other elements, upwards of one-third the weight of the solid crust of the earth, and eight-ninths by weight of water.

135. **Preparation.**—(1.) By exposing manganic oxide (binoxide of manganese) Mno_2 to a red heat in an iron bottle or retort:—

$$3MnO^2 = Mn_3O_4 + O_2$$

(2.) By heating in a glass retort a mixture of manganic oxide and sulphuric acid. These materials should be well mixed, or fracture of the retort will probably take place.

$$2MnO_2+2SO_2Ho_2 = 2OH_2+2SO_2Mno''+O_2$$

Manganous sulphate

(3.) By decomposing by heat in a hard glass tube red oxide of mercury (red precipitate)

$$2HgO = Hg_2+O_2$$

When mercury is heated to about 300°C, it slowly absorbs oxygen, forming red oxide of mercury.

(4.) By the decomposition of water by voltaic electricity:—

$$2OH_2 = O_2+2H_2$$

The apparatus for this purpose is a glass vessel filled with water, made slightly acid by the addition of a small quantity of sulphuric acid to enable it to conduct the electricity. Two test tubes filled with the same water are inverted in this glass vessel over two small platinum plates attached to wires of the same metal passing through the cork or caoutchouc stopper at the bottom of the vessel. On connecting these wires with the terminals of a galvanic battery, gas is seen to be given off from each plate, that evolved from the negative electrode being hydrogen gas,

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Sc. Ex., 1859.—Describe the usual processes for the preparation of oxygen gas. 135.

Sc. Ex., 1861.—Describe the preparation of oxygen by means of binoxide of manganese and sulphuric acid. 135 (2).

Sc. Ex., 1861 and 1862.—Describe a chemical process by which hydrogen, and one by which oxygen may be prepared from water. 135 (4).

Sc. Ex., 1868, E.—How would you prepare oxygen gas? Explain your process by an equation. 135.

Sc. Ex., 1869, E.—You have some mercury, a glass flask, and a piece of hard glass tube, and are required to make pure oxygen; how would you do it? 135. (3).

whilst that which comes off from the positive electrode is oxygen gas. The volume of hydrogen will be observed to be double that of the oxygen which is the proportion in which these gases combine to form water.

(5.) By heating in a retort a mixture of equal parts of manganic oxide and potassic chlorate (chlorate of potash). The manganic oxide undergoes no change, but the gas is given off at a lower temperature than when the potassic chlorate is used alone :—

$$2\begin{cases} OCl \\ OKo \end{cases} = 2KCl + 3O_2$$

(6.) By passing through a red-hot porcelain tube a mixture of steam and chlorine, when the chlorine unites with the hydrogen of the water, and oxygen is liberated :—

$$2OH_2 + 2Cl_2 = 4HCl + O_2$$

(7.) By dropping sulphuric acid into a red-hot platinum or porcelain tube, the sulphuric acid is broken up as follows :—

$$2SO_2Ho_2 = 2SO_2 + 2OH_2 + O_2$$

Oxygen is liberated, through the agency of sunlight, by the decomposition of carbonic anhydride CO_2 by the green leaves of plants :—

$$CO_2 = C + O_2$$

136. **Properties.** — Permanently gaseous, without colour, odour, or taste. Though not itself combustible, it is a very powerful supporter

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Sc. Ex., 1868, A.—Describe the chief properties of oxygen, hydrogen, and nitrogen, and state how you would prepare these bodies in a state of purity. 125, 124, 136, 135, 175, and 174.

of combustion. Bodies which burn in air, do so with increased brilliancy in pure oxygen. Phosphorus burnt in oxygen produces phosphoric anhydride, P_2O_5; sulphurous anhydride, SO_2; and carbonic anhydride, CO_2 are the products of the combustion of sulphur and charcoal respectively in oxygen. The volume of gas in the case of the phosphorus suffers a diminution; but as regards the sulphur and the charcoal, the volume of gas remains unaltered.

OZONE—ALLOTROPIC OXYGEN.

137. Symbol, O_3. Molecular weight, 48. 1 litre weighs 24 criths.

Schonbein. of Basle, gave this gas the name of ozone on account of its peculiar odour.

138. **Preparation.** — (1.) By allowing a stick of phosphorus to hang in a bottle filled with moist air, the oxygen in the air is converted into ozone, which may be recognised by the starch test given below.

(2.) By acting on potassic permanganate with strong sulphuric acid, oxygen is given off in the form of ozone.

(3.) It is produced in small quantities in the galvanic decomposition of water.

Sc. Ex., 1868, E.—I have two receivers filled with oxygen gas, in one I burn a fragment of sulphur, in the other a fragment of phosphorus; describe what takes place in each case, and state whether the volume of gas in the receivers will be diminished or augmented, or will remain unaltered. 136.

139. **Properties.**—It possesses bleaching and disinfecting properties, and as it is believed to exist in the air, it probably performs a useful part in the economy of nature. It is a powerful oxidising agent; it corrodes cork, and oxidises copper, iron, and even silver and mercury. When it oxidises a substance, its bulk is nŏt diminished, probably because only one of the atoms in the molecule of ozone is employed in oxidising, the other two atoms remaining to form a molecule of oxygen of exactly the same bulk as the ozone itself, thus:—

$$Ag_2 + \underset{\text{One molecule of ozone}}{O_3} = OAg_2 + \underset{\text{One molecule of oxygen}}{O_2}$$

140. **Test.**—If a piece of paper be dipped in a solution of potassic iodide and starch paste, it is turned blue by ozone, owing to the liberation of iodine and the formation of a blue compound of iodine and starch:—

$$2KI + OH_2 + O_3 = 2KHo + I^2 + O_2$$

WATER.

141. Symbol, OH_2. Molecular weight, 18. 1 litre weighs 9 criths.

Cavendish first discovered the composition of water.

142. **The composition of water** may be determined either by analysis or synthesis.

So. Ex., 1870, E.—Mention the composition of ozone, state its properties, and describe how you would prepare it. 138 and 139.

Analysis.—The decomposition of water by voltaic electricity proves that two volumes of hydrogen and one volume of oxygen unite to form water. The first, third, and fourth methods of preparing hydrogen are also processes for determining the composition of water by analysis.

Synthesis.—If a mixture of two volumes of hydrogen and one volume of oxygen be exploded in a strong glass tube standing over mercury, the whole of the mixture becomes water; whereas any proportions varying from these leave an excess of oxygen or hydrogen, as the case may be.

That water is formed by the combustion of hydrogen in air may be experimentally shown by holding a glass cylinder or tube over a burning jet of hydrogen, when the hydrogen will unite with the oxygen of the air and form water which will trickle down the sides of the tube or cylinder.

In every 18lbs. of water, there are 16lbs. of oxygen, and 2lbs. of hydrogen.

143. **Properties.**—Water is colourless; but in large masses it appears of a blue colour. It is without taste or smell, and is transparent. Its point of greatest density is 4°C.; it boils at 100°C. It evaporates at all temperatures. Is 815 times heavier than air; an imperial gallon weighing

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Sc. Ex., 1870, E.—Explain how you would demonstrate experimentally that water is formed by the combustion of hydrogen in air. 142.

Sc. Ex., 1870, E.—How would you demonstrate experimentally the composition of water and of air? 142 and 176.

Sc. Ex., 1862.—What is the composition of water by weight and by volume? 142.

10lbs. avoirdupois. A cubic metre of distilled water at 4°C weighs 1000 kilogrammes, and a litre weighs 1000 grammes. It is slightly compressible. Water is purified by distillation. It is a solvent for most substances. It transforms anhydrides into acids, thus:—

$$SO_2 + OH_2 = SOHo_2$$

Sulphurous anhydride — Sulphurous acid

$$P_2O_5 + 3OH_2 = 2POHo_3$$

Phosphoric anhydride — Phosphoric acid

Water also converts metallic oxides into hydrates.

144. **Hardness and Softness.**—A water which produces a lather with difficulty with soap is said to be hard water; whereas, when a lather is produced easily, the water is said to be soft. Water which exhibits seven or more degrees of hardness is termed hard water; if below seven degrees it is termed soft water. Calcic and magnesic carbonates give hardness to water; but they may be removed to a great extent by boiling the water, or by adding lime to it. As these carbonates are removeable, the hardness of the water containing them is said to be temporary; when, however, the water is rendered hard by having calcic sul-

Sc. Ex., 1859.—What is meant by the term *hardness* when applied to water? 144.

Sc. Ex., 1861.—What is the meaning of the term *hardness*, applied to water? 144.

Sc. Ex., 1869, A.—What is meant by the term *hardness* as applied to water, and what is the difference between *temporary* and *permanent* hardness? 144.

phate in solution, it is said to be **permanently hard**, because the calcic sulphate cannot be removed without introducing other objectionable substances.

145 **Hydroxyl.**—H_2O_2 or $(HO)_2$ or Ho_2 or $\left\{\begin{matrix}OH\\OH\end{matrix}\right.$

This substance is also called peroxide of hydrogen, binoxide of hydrogen, and oxygenated water.

146. **Preparation.** — (1) By suspending baric peroxide in ice-cold water, and passing carbonic anhydride through the water for some time. The containing vessel should be surrounded by ice.

$$\left\{\begin{matrix}O\\O\end{matrix}\right.Ba'' + CO_2 + OH_2 = COBao'' + \left\{\begin{matrix}OH\\OH\end{matrix}\right.$$

Baric peroxide	Carbonic anhydride	Baric carbonate	Hydroxyl

(2.) By dissolving baric peroxide in hydrochloric acid, carefully cooled by ice.

$$\left\{\begin{matrix}O\\O\end{matrix}\right.Ba'' + 2HCl = BaCl_2 + \left\{\begin{matrix}OH\\OH\end{matrix}\right.$$

The barium is precipitated by cautiously adding sulphuric acid:—

$$BaCl_2 + SO_2Ho_2 = SO_2Bao'' + 2HCl$$

The chlorine of the hydrochloric acid is removed by adding a solution of argentic sulphate:—

$$SO_2Ago_2 + 2HCl = SO_2Ho_2 + 2AgCl$$

Sc. Ex., 1869, E.—How is hydroxyl (peroxide of hydrogen) prepared; what are the relations of this substance to water and slaked lime, and to what useful purpose has it been applied? 146 and 147.

The sulphuric acid is precipitated by the addition of baryta water :—

$$SO_2Ho_2 + BaHo_2 = SO_2Bao'' + 2OH_2$$

The insoluble precipitates, in all the above stages, must be filtered off; the last fluid will contain nothing but hydroxyl and water, the latter of which may be removed by placing it under an air-pump, and continuously exhausting until the fluid has acquired the specific gravity of 1·45.

147. **Properties.** — It is a transparent syrupy liquid, without colour or smell, possessing powerful bleaching properties. At the least elevation of temperature it effervesces, giving off oxygen gas. When it is raised to 100° it explodes. It is very liable to decomposition. It is a powerful oxidizing agent. The fact that hydroxyl converts plumbic sulphide (PbS) into plumbic sulphate (SO_2Pbo'') has been turned to good account in the restoration of oil paintings which have become blackened by the conversion of the lead into sulphide. Its most remarkable property is its power to reduce argentic oxide (OAg_2) to the metallic state :—

$$\begin{cases} OH \\ OH \end{cases} + OAg_2 = OH_2 + O_2 + Ag^2$$

OXIDES

AND

OXY-ACIDS OF CHLORINE.

148 **There are three oxides known,** namely, hypochlorous anhydride, chlorous anhydride, and chloric peroxide; and there are four

oxy-acids, hypochlorous, chlorous, chloric, and perchloric acid.

149. **Hypochlorous Anhydride** (OCl_2) is prepared by the action of chlorine upon mercuric oxide; the chlorine combines not only with the metal, but also with the oxygen, thus :—

$$\underset{\text{Mercuric oxide}}{2HgO} + 2Cl_2 = \underset{\text{Mercuric oxy-chloride}}{\begin{cases} HgCl \\ O \\ HgCl \end{cases}} + OCl_2$$

It is a pale yellow gas, which may be condensed by means of a freezing mixture to a red liquid, which is very explosive. It is decomposed by water, forming hypochlorous acid ($ClHo$), which yields hypochlorites when acted on by metallic oxides or hydrates, thus :—

$$\underset{\text{Sodic hydrate}}{ONaH} + ClHo = \underset{\text{Sodic hypochlorite}}{ClNao} + OH_2$$

150. **Calcic chloro-hypochlorite**, called also **bleaching powder** and **chloride of lime**, is made by passing chlorine gas into a low room, on the floor of which a layer of slaked lime, two inches thick, is laid until no more gas is absorbed. The reaction is as follows :—

$$\underset{\text{Calcic hydrate}}{CaHo_2} + Cl_2 = \underset{\text{Calcic chloro-hypochlorite}}{Ca(OCl)Cl} + OH_2$$

Sc. Ex., 1862.—How is bleaching powder prepared? 150.

Acids liberate free chlorine from bleaching powder, thus:—

$$\text{Ca (OCl) Cl} + 2\text{HCl} = \text{CaCl}_2 + \text{OH}_2 + \text{Cl}_2 \; .$$

151. **Chlorous Anhydride** $\left\{\begin{array}{l}\text{OCl}\\ \text{O}\\ \text{OCl}\end{array}\right.$, is prepared by heating in a flask a mixture of potassic chlorate, arsenious acid, and nitric acid. It is decomposed by water, forming chlorous acid (OClHo), a greenish yellow liquid, possessing strong bleaching and oxidizing properties. With bases it forms chlorates. Chlorous anhydride is a greenish yellow gas, which liquefies with extreme cold.

152. **Chloric Peroxide,** $\left\{\begin{array}{l}\text{OCl}\\ \text{O}\\ \text{O}\\ \text{OCl}\end{array}\right.$, is prepared by heating a mixture of powdered potassic chlorate and sulphuric acid. The gas has a very powerful odour.

$$3\left\{\begin{array}{l}\text{OCl}\\ \text{OKo}\end{array}\right. + \text{SO}_2\text{Ho}_2 = \left\{\begin{array}{l}\text{OCl}\\ \text{O}\\ \text{OKo}\end{array}\right. + 2\text{SO}_2\text{KoHo} + \left\{\begin{array}{l}\text{OCl}\\ \text{O}\\ \text{O}\\ \text{OCl}\end{array}\right.$$

Potassic chlorate — Potassic perchlorate — Hydric-potassic sulphate — Chloric peroxide

$$+ \text{OH}_2$$

153. **Chloric Acid,** $\left\{\begin{array}{l}\text{OCl}\\ \text{OHo}\end{array}\right.$, is obtained by adding to a solution of baric chlorate, dilute sulphuric acid, thus:—

$$\left\{\begin{array}{l} OCl \\ O \\ Bao'' \\ O \\ OCl \end{array}\right. + SO_2H_2 = 2\left\{\begin{array}{l} OCl \\ OHo \end{array}\right. + SO_2Bao''$$

Baric chlorate — Chloric acid — Baric sulphate

154. **Chlorates** are obtained by passing chlorine gas through a solution of a hydrate; thus, potassic chlorate is made by passing chlorine through a warm solution of potassic hydrate :—

$$6KHo + 3Cl_2 = \left\{\begin{array}{l} OCl \\ OKo \end{array}\right. + 5KCl + 3OH_2$$

Potassic hydrate — Potassic chlorate — Potassic chloride

The chlorate can be easily separated by crystallization from the more soluble chloride.

155. **Perchloric Acid,** $\left\{\begin{array}{l} OCl \\ O \\ OHo \end{array}\right.$, is obtained by distilling potassic perchlorate with sulphuric acid :—

$$2\left\{\begin{array}{l} OCl \\ O \\ OKo \end{array}\right. + SO_2Ho_2 = 2\left\{\begin{array}{l} OCl \\ O \\ OHo \end{array}\right. + SO_2Ko_2$$

Potassic perchlorate — Perchloric acid

Perchloric acid, when pure, is a colourless liquid, and is one of the most powerful oxidising agents known. When thrown upon charcoal or other organic substances, it explodes with fearful violence.

Sc. Ex., 1862.—How is chloric acid prepared? 153.

Sc. Ex., 1860.—Give the composition and the preparation of chloric and perchloric acids. 153 and 155.

156. **Potassic perchlorate** is made by heating potassic chlorate until one-third of the oxygen is given off; the substance then consists of a mixture of potassic chloride and perchlorate, which can be separated by crystallization :—

$$2\left\{\begin{matrix}OCl\\OKo\end{matrix}\right. = KCl + \left\{\begin{matrix}OCl\\O\\OKo\end{matrix}\right. + O_2$$

Potassic chlorate   Potassic chloride   Potassic perchlorate

BORON.

157. Symbol, B. Atomic weight, 11. Probable molecular weight, 22. Atomicity, III.

158. **Occurrence in Nature.**—Boron, in combination with oxygen and sodium, is found as borax in nature. It is also found combined with oxygen in the lagoons of Tuscany, as boric acid.

159. **Preparation.**—Boron exists in three allotropic forms :—Amorphous boron is a brownish powder obtained by heating boric anhydride with sodium :—

$$B_2O_3 + 3Na_2 = 3ONa_2 + B_2$$

Graphitoidal boron is obtained when boric chloride is passed over melted aluminium :—

$$Al_2 + 2BCl_3 = Al_2Cl_6 + B^2$$

It crystallizes in thin opaque six-sided plates.

Diamond boron is made by fusing boric anhydride with aluminium :—

$$Al_2 + B_2O_3 = Al_2O_3 + B_2$$

The crystals are eight-sided, of a brownish colour, and exceedingly hard, as they will scratch the ruby.

Boric anhydride (B_2O_3) is prepared by fusing boric acid at a red heat:—

$$2BHo_3 = B_2O_3 + 3OH_2$$

Boric acid, BHo_3, (boracic acid) is obtained by adding hydrochloric acid to a hot solution of borax:—

$$\underset{\text{Borax}}{B_4O_5Nao_2} + 2HCl + 5OH_2 = \underset{\text{Boric acid}}{4BHo_3} + 2NaCl$$

Boric chloride (BCl_3) is prepared by acting on fused boric anhydride and charcoal with dry chlorine:—

$$\underset{\text{Boric anhydride}}{B_2O_3} + 3Cl_2 + C_3 = \underset{\text{Boric chloride}}{2BCl_3} + \underset{\text{Carbonic oxide}}{3C''O}$$

160. **Borax** ($B_4O_5Nao_2$) is employed for soldering metals, forming the glazes for porcelain, and as a flux for examining metallic compounds before the blowpipe. A salt of manganese heated in the outer flame of the blowpipe, with the borax on a piece of platinum wire, gives a violet-coloured bead; cobalt, blue; chromium, green; and copper, red. Boric nitride (BN) is obtained when heated boron is burnt in nitrogen gas.

CARBON.

161. Symbol, C. Atomic weight, 12. Atomicity, IV (sometimes reduced to II).

162. **Occurrence in Nature.**—It is found in nature as the diamond, and graphite or

black-lead. Charcoal, coke, soot, bone-black, and lamp-black are examples of artificial carbon. It exists in the air in combination with oxygen as carbonic anhydride, and it is also found dissolved in spring water.

163. **Preparation.**—Charcoal is prepared by burning animal or vegetable substances with a limited supply of air. Lamp-black is obtained by burning tar, oil, or resin. The lamp-black is deposited in fine powder in the upper part of the chimney. Coke is prepared by burning coal in closed retorts, as in the manufacture of gas. Plumbago, or black lead, is obtained from mines in Cumberland. Diamonds are carbon in the crystallized form.

164. **Properties.**—It is solid, without taste, and generally of a black colour, although it is sometimes found without colour, as in the diamond. It assumes three allotropic forms,—the **diamond**, the **graphitoidal**, as in black-lead or graphite, and the **amorphous**, as in charcoal and lamp-black. It is insoluble in water and other liquids; has a great affinity for oxygen at high temperatures; and is very combustible. It is used for the manufacture of pencils, Indian ink, black crayons, and for purifying water. Animal charcoal is used as a decolourising agent in sugar refineries.

CARBONIC ANHYDRIDE.

165. Symbol, CO_2. Specific gravity, 22.

166. **Occurrence in Nature.**—It is an important constituent of the atmosphere; is pre-

sent in spring water; is evolved from volcanoes; and is produced by respiration. It is given off in the process of fermentation, and forms the **choke-damp** of the coal mines.

167. **Preparation.**—(1.) By burning charcoal (carbon) in oxygen.

(2.) By decomposing calcic carbonate with hydrochloric acid:—

$$\underset{\text{Calcic carbonate}}{COCao''} + 2HCl = \underset{\text{Calcic chloride}}{CaCl_2} + OH_2 + \underset{\text{Carbonic anhydride}}{CO_2}$$

168. **Properties.** — A transparent and colourless gas, with a slightly acid taste and smell. It may be liquefied by a pressure of sixty atmospheres. It neither supports combustion, nor is it combustible. It acts as a narcotic poison, and rapidly destroys animal life. It is decomposed by passing over red-hot charcoal or iron.

CARBONIC OXIDE.

169. Symbol, $C''O$ Specific gravity or density, 14.

170. **Preparation.**—(1.) By passing carbonic anhydride through a red-hot iron tube filled with iron borings:—

$$4CO_2 + Fe_3 = \underset{\text{Magnetic oxide}}{Fe_3O_4} + \underset{\text{Carbonic oxide}}{4CO}$$

(2.) By passing carbonic anhydride through a red-hot porcelain tube filled with charcoal:—

$$CO^2 + C = 2CO$$

This gas is often produced in a similar manner in an ordinary red-hot coal-fire; the oxygen of the air, which enters at the bottom of the grate, combines with the carbon of the coal, forming carbonic anhydride; this substance then passes through the red-hot part of the fire and parts with half of its oxygen to the red-hot carbon, the carbonic anhydride being converted into carbonic oxide which burns at the surface with a blue flame, and is again changed into carbonic anhydride.

(3.) By heating sulphuric acid with oxalic acid. The sulphuric acid abstracts one molecule of water from the oxalic acid, leaving C_2O_3, which cannot exist alone, but immediately breaks up into a mixture of carbonic oxide and carbonic anhydride.

$$\left\{\begin{matrix} COHo \\ COHo \end{matrix}\right. = OH_2 + C''O + CO_2$$

Oxalic acid

171. **Properties.** — It is a transparent, colourless, tasteless, and inodorous gas. It is slightly soluble in water. It is an exceedingly strong poison. It burns in air or oxygen, forming carbonic anhydride. It does not support either combustion or respiration. At high temperatures it is a reducing agent.

NITROGEN.

172. Symbol, N. Atomic weight and sp.gr., 14. Molecular weight, 28. 1 litre weighs 14 criths. Atomicity, V. (frequently III., sometimes I).

Discovered by Lavoisier in 1775.

173. **Occurrence in Nature.**—It occurs in a state of combination in the bodies of plants and animals in various chemical compounds, such as nitre, whence it derives its name. It constitutes about four-fifths by bulk of the atmosphere, in which it exists in the free state. It is contained in coal, and in potassic and sodic nitrates.

174. **Preparation.** — (1.) By burning a piece of phosphorus in a bell jar filled with air and standing over water, by which phosphoric anhydride is produced, and nitrogen liberated. One-fifth of the volume of the air consisting of oxygen will have disappeared, and its place will be supplied by the water which will rise up in the jar.

(2.) By passing a current of chlorine through a solution of ammonia :—

$$8NH_3 + 3Cl_2 = 6NH_4Cl + N_2$$

If the chlorine be present in excess, a most dangerous and explosive compound is formed.

(3.) By passing air over red-hot metallic copper; the copper takes up the oxygen, and the nitrogen passes forward and may be collected :—

$$2Cu + \underbrace{4N_2 + O_2}_{\text{Air}} = 2CuO + 4N_2$$

Sc. Ex., 1869, E.—State exactly how you would prepare nitrogen, nitric oxide, and ammonia. Give equations. 174, 182, and 197.

Sc. Ex., 1865.—Describe two essentially different processes for the preparation of nitrogen gas. 174.

Sc. Ex., 1868, A.—Describe the chief properties of oxygen, hydrogen, and nitrogen, and state how you would prepare these bodies in a state of purity. 125, 124, 136, 135, 175, and 174.

(4.) By allowing a mixture of iron filings, sulphur, and water to remain under a gas jar for twenty-four hours. The oxygen of the air is absorbed, and nitrogen only remains.

(5.) By heating ammonic nitrite :—

$$\underset{\text{Ammonic nitrite}}{\mathbf{N}'''O''_2(N^{v}H_4O)'} = N + 2\mathbf{O}H_2$$

175. **Properties.** — Permanently gaseous, without colour, taste, or smell. It is neither a supporter of combustion nor respiration, nor is it combustible. Its properties are remarkably inactive; but in combination it forms compounds of a very energetic and powerful character.

ATMOSPHERIC AIR.

176. **Composition.** — It is a mixture of nitrogen with oxygen, together with several other important constituents, such as carbonic anhydride, aqueous vapour, and ammonia gas.

The following is the per-centage composition of the atmosphere when it is free from moisture and carbonic anhydride :—

	By weight.	By volume.
Nitrogen	76·9	79·1
Oxygen	23·1	20·9
	100	100

The air may be analysed in the following manner :—

Introduce a piece of phosphorus, by means of a wire, into a graduated glass tube standing over

water. The quantity of air in the tube is easily determined by observing the point to which the water rises in the graduated tube. The whole is now left for twenty-four hours. The oxygen combines with the phosphorus, forming phosphoric anhydride, which dissolves in water. When the phosphorus is withdrawn, the residual gas is nitrogen. The amount of oxygen in the air may also be found by the process given under the third mode of making nitrogen. Air may also be analysed by mixing it with an excess of hydrogen in a graduated tube called a **eudiometer**, and exploding the mixture by an electric spark; the hydrogen and oxygen form water which condenses, and the remaining volume of gas is read off; the diminution represents exactly the volumes of these gases which have united. As two volumes of hydrogen always unite with one volume of oxygen to form water, one-third of the diminution in volume must represent the oxygen which has disappeared, and, therefore, the volume of oxygen contained in the air taken.

Sc., Ex., 1860.—Give the composition of the atmosphere, and describe the methods employed in determining its constituents. 176.

Sc. Ex., 1870, E.—How would you demonstrate experimentally the composition of water and of air? 176 and 142.

Sc. E., 1861.—State the constituents of the atmosphere, and the proportion by volume in which they are present. 176.

Sc. Ex., 1862.—Describe one of the methods of estimating the amount of oxygen in atmospheric air. 176.

177. **The following proofs** may be given to show that the air is a mixture, and not a chemical compound:—

(1.) When oxygen and nitrogen are mixed together in the proportions in which they are found in the air, no rise in temperature or alteration in bulk takes place, as is invariably the case when gases combine, and the mixture has all the properties of air.

(2.) The density of the air is the same as the density of the foregoing mixture of the two gases, which could not be the case if the air were a compound.

NITROUS OXIDE (Laughing Gas).

178. Symbol, $\mathbf{O}N_2$. Density, 22.

179. **Preparation.**—By decomposing ammonic nitrate by heat in a flask or retort:—

$$\mathbf{N}^{v}O_2(N^{v}H_2O) = 2\mathbf{O}H_2 + \mathbf{O}N_2$$

180. **Properties.**—It is a transparent gas, without colour, having a sweet taste. Like oxygen, it supports combustion. Cold water dissolves nearly its own volume of this gas. It should be collected over warm water. Dentists and surgeons use it as an anæsthetic, that is, a substance for producing insensibility to pain for a short time.

NITRIC OXIDE.

181. Symbol, $\left\{\begin{matrix}\mathbf{N}O.\\ \mathbf{N}O.\end{matrix}\right.$ Density, 15.

182. **Preparation.**—By acting upon copper turnings with nitric acid:—

$$8NO_2Ho+3Cu=3\begin{cases}NO_2\\Cuo''\\NO_2\end{cases}+\begin{cases}NO\\NO\end{cases}=4OH_2$$

Nitric acid Cupric nitrate Nitric oxide

183. **Properties.**—It is a colourless and transparent gas, producing when in contact with air or oxygen red fumes, which are readily soluble in water, and by this property it may be distinguished from all other gases. In the manufacture of sulphuric acid, nitric oxide acts as a carrier of oxygen.

NITROUS ANHYDRIDE.

184. Symbol, $\begin{cases}NO\\O\\NO\end{cases}$ Density, 38

185. **Preparation.**—By mixing four volumes of dry nitric oxide with one volume of oxygen, and exposing the mixture to as low a temperature as can be obtained by freezing mixtures. It may also be prepared by heating nitric acid with starch, and by dissolving silver in dilute nitric acid.

186. **Properties.**—A thin mobile, indigo-blue coloured liquid.

Liquid nitrous anhydride boils at 0°C., giving off orange-red fumes.

Sc. Ex., 1869, E.—State exactly how you would prepare nitrogen, nitric oxide, and ammonia. Give equations. 174, 182, and 197.

NITRIC PEROXIDE (Nitrous Gas).

187. Symbol, $\begin{cases} NO_2 \\ NO_2 \end{cases}$ Density, 23.

188. **Preparation.**—By heating plumbic nitrite in a hard glass retort:—

$$\underset{\text{Plumbic nitrate}}{2N_2O_4Pbo''} = 2PbO + \underset{\text{Nitric peroxide}}{2N_2O_4} + O_2$$

189. **Properties.**—It is a deep brownish red gas, possessing a suffocating odour. It is soluble in water, and converts metallic hydrates and oxides into a mixture of nitrates and nitrites. It is without either acid or basic properties.

NITRIC ANHYDRIDE.

190. Symbol $\begin{cases} NO_2 \\ O \\ NO_2 \end{cases}$ Density, 54.

191. **Preparation.**—By passing dry chlorine gas over dried argentic nitrate heated to 95°C., the anhydride being condensed by a freezing mixture:—

$$\underset{\substack{\text{Argentic} \\ \text{nitrate}}}{4NO_2Ago} + 2Cl_2 = 4AgCl + \underset{\substack{\text{Nitric} \\ \text{anhydride}}}{2N^v{}_2O_5} + O_2$$

It is a very unstable white crystalline substance.

NITROUS ACID (NOHo).

192. This acid is the result of the action of water on nitrous anhydride. It forms nitrites with oxides and hydrates. Potassic nitrite (NOKo)

Sc. Ex., 1868, E.—Give the names and formulæ of the principal compounds of nitrogen with oxygen and hydrogen. 178, 181, 184, 187, 190, 192, 193, 196, and 199.

is obtained by heating nitre or potassic nitrate (NO_2Ko), when one of the atoms of oxygen is evolved.

NITRIC ACID, (Aquafortis) NO_2Ho.

193. **Preparation.**—By heating in a retort equal weights of nitre and sulphuric acid. The nitric acid distils over, and may be collected in a flask cooled with a wet cloth:—

$$\underset{\text{Potassic nitrate}}{2NO_2Ko} + SO_2Ho_2 = \underset{\text{Nitric acid}}{2NO_2Ho} + \underset{\text{Potassic sulphate}}{SO_2Ko_2}$$

On a large scale, this acid is prepared in iron retorts, and collected in large earthenware condensing vessels; sodic nitrate being used instead of potassic nitrate.

194. **Properties.**—It is a colourless liquid when pure, but usually slightly yellow owing to the presence of lower oxides of nitrogen. It fumes when exposed to the air. It is a strong oxidizing agent, attacking most of the metals with great violence. When mixed with hydrochloric acid it forms *aqua regia*. It forms nitrates with bases, nearly all of them being soluble in water.

195. **Test.**—By adding to the liquid to be tested an equal volume of strong sulphuric acid, well cooling the mixture, and pouring on to its surface a strong solution of ferrous sulphate. If any nitric acid be present, a black ring is produced where the two layers of liquid meet.

Sc. Ex., 1865.—How is nitric acid prepared? Represent the reaction in an equation. 193.

AMMONIA.

196. Symbol, $N'''H_3$ Density, 8·5.

This substance is sometimes called the **volatile alkali**, and sometimes spirits of **hartshorn**. It is produced in the decomposition of animal or vegetable matter containing nitrogen and hydrogen.

197. **Preparation.**—By heating in a flask a mixture of ammonic chloride (sal-ammoniac) and quicklime, the gas being collected over mercury :

$$\underset{\text{Ammonic chloride}}{2NH_4Cl} + \underset{\text{Calcic oxide}}{CaO} = \underset{\text{Calcic chloride}}{CaCl_2} + \underset{\text{Ammonia}}{2NH_3} + OH_2$$

Liquid ammonia is prepared by passing the gas into water, in which it is very soluble.

Ammonia and its compounds are new principally obtained from the ammoniacal liquors of the gas-works.

198. **Properties.**—It is a colourless gas, having a suffocating odour. It liquefies under a pressurs of seven atmospheres. It is a powerful base; it combines with, and neutralizes the strongest acids, forming ammonic salts, thus :—

$$N'''H_3 + HCl = \underset{\text{Ammonic chloride}}{N^{v}H_4Cl\ (AmCl)}$$

$$2NH_3 + SO_2Ho_2 = \underset{\text{Ammonic sulphate.}}{SO_2Amo_2}$$

$$NH_3 + NO_2Ho = \underset{\text{Ammonic nitrate}}{NO_2Amo}$$

Sc. Ex., 1869, E.---State exactly how you would prepare nitrogen, nitric oxide, and ammonia. Give equations. 174, 182, and 197.

Sc. Ex., 1861.---Describe the preparation and properties of ammonia. 197 and 198.

It is very soluble in water. It is decomposed at a red heat. It is not combustible, or a supporter of combustion.

(AMMONIUM, NH_4.)

199. **This compound radical** is regarded as a metal by some chemists because it forms, with mercury, an amalgam, having metallic lustre, and all the properties of any other amalgam. It is the compound basylous element in all ammonic salts.

AMMONIC SALTS.

AMMONIC CHLORIDE (Sal-ammoniac).

200. Symbol, NH_4Cl or AmCl.

It is prepared from gas or bone liquor by adding to the solution a slight excess of hydrochloric acid, by means of which the ammonic carbonate, and ammonic sulphide contained in these liquids are decomposed with evolution of carbonic anhydride, and sulphuretted hydrogen, SH_2. To expel the tarry matter contained in the liquid, it is evaporated to dryness, and the salt carefully heated; it is afterwards purified by sublimation in iron vessels lined with clay and covered with domes of lead. It was originally prepared by subliming camel's dung.

AMMONIC NITRATE (NO_3Amo).

201. This nitrate is prepared by adding to ammonic carbonate, dilute nitric acid until the solution is neutralized, and slowly evaporating at a moderate temperature. It crystallizes in six-sided prisms.

AMMONIC SULPHATE, SO_4Amo_2, or $SO_4(NH_4O)_2$

202. It is prepared from gas liquor by neutralization with sulphuric acid. It may also be obtained in a purer state by neutralizing ammonic carbonate ($COAmo_2$) with sulphuric acid. It crystallizes in long six-sided prisms.

AMMONIC CARBONATES.

203. (1)—**Hydric-ammonic carbonate** (bi-carbonate of ammonia) $COHAmo$, is obtained by saturating ammonic hydrate with carbonic anhydride.

(2) **Ammonic carbonate** ($COAmo_2$) has never been obtained in the solid state.

Commercial ammonic carbonate is a mixture of the above two kinds, in the proportion of two molecules of $COHAmo$, and one molecule of $COAmo_2$. It is prepared by heating to redness in a retort a mixture of two parts of ammonic chloride, and one part of chalk.

HYDRIC-AMMONIC SULPHIDE ($SHAm$)

204. This useful compound is obtained by saturating a solution of ammonia with sulphuretted hydrogen. It is used for the purpose of precipitating many metals from their solutions.

AMMONIC SULPHIDE (SAm_2).

205. It is prepared by distilling SK_2 (potassic sulphide), or SNa_2 (sodic sulphide), with ammonic chloride or ammonic sulphate.

206. **Tests.**—Ammonic salts may easily be recognised by their giving off a gas possessing a pungent smell of ammonia when they are heated with caustic lime or a caustic alkali; or by its odour and the white fumes produced when a glass rod, moistened with hydrochloric acid (not fuming acid), is brought near to a salt acted on as above.

Nessler's test.—Add caustic potash to a solution containing an ammoniacal salt or free ammonia, to which add a solution of mercuric iodide in potassic iodide, and a brown precipitate or colouration is produced.

SULPHUR.

207. Symbol, S. Atomic weight and sp.gr. of vapour, 32. Molecular weight, 64. 1 litre weighs 32 criths. Atomicity, VI., IV., and II.

208. **Occurrence in Nature.**—Sulphur is found in the free state in volcanic districts, and is imported to this country from Sicily, Tuscany, and Naples. It is found in combination with several metals as sulphides. In union with oxygen it is found combined with calcium, barium, strontium, &c., as sulphates; and it is also present in small quantities in all animal and vegetable substances.

209. **Properties.**—This element, at ordinary temperatures, is a solid, of a pale yellow colour, having a peculiar and characteristic odour. It is a bad conductor of heat and electricity. At a temperature of 110°C., it melts into a thin amber-coloured liquid; at a temperature of 220°, it becomes thick and black, like treacle; and at 420° it boils. The condensed vapour forms sub-

limed sulphur, or **flowers of sulphur.** It is insoluble in water, but soluble in the bisulphide of carbon and essential oils. When heated to about 240°, it readily takes fire and burns with a blue flame, taking up oxygen, and forming sulphurous anhydride, SO_2. It combines with carbon at a red heat, forming the bisulphide of carbon. Sulphur has several allotropic forms, the following being the principal of them :—

(1) Octahedral crystals, as in native sulphur.
(2) Prismatic crystals, as in roll sulphur.
(3) Plastic or amorphous sulphur.
(4) Powder of a yellow or orange colour.

210. **Uses.**—For the manufacture of gunpowder, lucifer matches, sulphuric and sulphurous acids, and in medicine.

COMPOUNDS OF SULPHUR,

WITH BASYLOUS ELEMENTS.

SULPHURETTED HYDROGEN, OR HYDROSULPHURIC ACID.

211. Symbol, SH_2 Density, 17.

212. **Occurrence in Nature.**— It is found evolved from volcanoes, and in spa waters, and in waters containing both organic matter and sulphates. It is constantly produced in the decay of animal and vegetable matter.

213. **Preparation.**—(1) By acting on ferrous sulphide with dilute sulphuric acid :—

$$FeS + SO_2Ho_2 = SH_2 + SO^2Feo''$$

Hydrochloric acid may be used instead of the sulphuric acid; and the ferrous sulphide (**FeS**)

can be made by fusing together equal quantities of iron filings and sulphur.

(2) By heating antimonious sulphide with strong hydrochloric acid in a gas bottle, pure sulphuretted hydrogen is obtained:—

$$\underset{\text{Antimonious sulphide}}{Sb_2S_3} + 6HCl = \underset{\text{Antimonious chloride}}{2SbCl_3} + 3SH_2$$

(3) By heating sulphur in hydrogen gas.

214. **Properties.** — It is a transparent, colourless gas, having a strong disagreeable odour, like rotten eggs. The inhalation of this gas is very injurious, and chlorine is employed to decompose it. It is very soluble in water, the solution being used in the laboratory as a test.

215. **Uses.**—It is used as a general or group re-agent by the analyst. It precipitates the following metals as sulphides from acid solutions of any of their salts:—Pb., Cu., Bi., Cd., Hg., Sn., Sb., Au., and Pt., and the following metals from solutions of their salts previously made alkaline by addition of ammonic hydrate:—Fe., Co., Ni., Mn., and Zn. as sulphides, Cr. and Al. as hydrates. Sulphuretted hydrogen in some cases acts as a reducing agent, as in the following example:—

$$\underset{\text{Ferric chloride}}{2Fe'''_2Cl_6} + SH_2 = \underset{\text{Ferrous chloride}}{4Fe''Cl_2} + 4HCl + S_2$$

Sc. Ex., 1868, E.—You have given to you iron filings, sulphur, and hydrochloric acid, and are required to make sulphuretted hydrogen; how will you proceed? 213 (1).

Sc. Ex., 1868, A.—Give the names and formulæ of the compounds of sulphur with oxygen and hydrogen. 211, 216, 220, 222, 223, 224, and 226.

Sc. Ex., 1861.—How is sulphuretted hydrogen prepared? 213.

HYDROSULPHYL, S_2H_2, or Hs_2.

216. This substance, called also persulphide of hydrogen, is prepared by mixing a solution of calcic disulphide with hydrochloric acid:—

$$CaS_2 + 2HCl = S_2H_2 + CaCl_2$$

It performs the same functions in sulphydrates that hydroxyl (Ho) does in hydrates, *e.g.*—

Zincic hydrate, $ZnHo_2$; Zincic sulphydrate, $ZnHs_2$.

CARBONIC DISULPHIDE, CS''_2.

217. Discovered by Lampadius in 1796. It is also called bisulphide of carbon.

218. **Preparation.**—It is prepared by passing the vapour of sulphur through an iron cylinder containing charcoal heated to redness. The gaseous product passes over into a well-cooled condenser, where it liquefies:—

$$C + S_2 = CS_2$$

219. **Properties.**—It is a thin, mobile, colourless liquid, with a most disagreeable odour, and very volatile. Its vapour is poisonous. It is insoluble in water, but very soluble in alcohol. It dissolves iodine, bromine, phosphorus, oils, fats, gutta-percha, india-rubber, &c. Being a good refractor of light, it is used for filling prisms for experiments on light. It is employed to extract oils from seeds and refuse wool.

COMPOUNDS OF SULPHUR

WITH OXYGEN AND HYDROXYL.

SULPHUROUS ANHYDRIDE, $S^{iv}O_2$.

220. **Preparation.**—(1) By burning sulphur in air or oxygen:—

$$S_2+2O_2 = 2SO_2$$

(2) By heating in a flask, copper, mercury, or charcoal with sulphuric acid:—

$$2SO_2Ho_2+Cu = SO_2Cuo''+2OH_2+SO_2$$
$$2SO_2Ho_2+C = CO_2+2OH_2+2SO_2$$

221. **Properties.**—A transparent, colourless gas, possessing a suffocating smell of burning sulphur. It liquefies at $-10°C.$, or under a pressure of two atmospheres at the ordinary temperature. It is very soluble in water, one volume of water dissolving 69 volumes of this gas. It is employed for bleaching straw used in plaiting, and woollen goods. It is also used as a disinfectant and antiseptic.

SULPHUROUS ACID, $SOHo_2$.

222. This substance is produced when sulphurous anhydride combines with water. It is a powerful reducing agent. It reduces ferric salts to the ferrous condition, thus:—

$$\underset{\text{Ferric sulphate}}{S_3O_6\,(Fe_2O^6)^{vi}}+\underset{\text{Sulphurous acid}}{SOHo_2}+OH_2 = \underset{\text{Ferrous sulphate}}{2SO_2Feo''}+\underset{\text{Sulphuric acid}}{2SO_2Ho_2}$$

SULPHURIC ANHYDRIDE, SO_3.

223. This substance is a white, solid, crystalline body, which may be prepared by heating Nordhausen sulphuric acid in a retort, provided with a receiver, surrounded by a freezing mixture. It may also be obtained by heating sulphuric acid with phosphoric anhydride in a retort. Sulphuric anhydride does not redden litmus paper; but when brought into contact with water, it hisses as a red-hot iron would do, forming sulphuric acid.

SULPHURIC ACID, SO_2Ho_2.

224. This substance, called also Oil of Vitriol, is the most important and useful acid known, as by its means nearly all the other acids are prepared, and also because it is of very great use in the arts and manufactures.

225. **Preparation.**—The method usually adopted in preparing this acid depends on the formation of sulphurous anhydride, and its subsequent oxidation into sulphuric acid. **Sulphur**, or **iron pyrites**, is burnt in a suitable furnace freely supplied with air; the flame of the sulphur heats an iron pot or crucible containing a mixture of sodic nitrate and sulphuric acid, which gives off mixed fumes of nitric acid and nitric peroxide. These, accompanied with the sulphurous anhydride, pass into a large leaden chamber, the floor of which is covered with water to the depth of a few inches, and into which jets of steam are made to play. At the end of the chamber an exit tube is provided for the spent gases. By this arrangement a constant supply of sulphurous acid, nitric acid, water, and air is provided.

The following reactions take place within the vitriol chamber:—The nitric acid vapour gives up part of its oxygen to the sulphurous anhydride, converting it into sulphuric acid, and becoming itself reduced to nitric peroxide, thus:—

$$\underset{\text{Nitric acid}}{2NO_2Ho} + \underset{\text{Sulphurous anhydride}}{SO_2} = \underset{\text{Sulphuric acid}}{SO_2Ho_2} + \underset{\text{Nitric peroxide}}{N_2O_4}$$

The nitric peroxide undergoes further deoxidation until it is reduced to nitric oxide, thus:—

$$\underset{\text{Nitric peroxide}}{N_2O_4} + 2SO_2 + 2OH_2 = 2SO_2Ho_2 + \underset{\text{Nitric oxide}}{N_2O_2}$$

The nitric oxide coming in contact with the oxygen of the air, becomes once more nitric peroxide, which is again reduced by the action of a fresh supply of sulphurous anhydride. Thus the nitrogen compounds act the part of carriers of oxygen from air to the sulphurous acid. At intervals the acid is drawn off from the floor of the leaden chamber, and is deprived of any excess of water by evaporating in shallow leaden pans.

NORDHAUSEN SULPHURIC ACID, $\left\{\begin{array}{l} SO_2Ho \\ O \\ SO_2Ho \end{array}\right.$

226. This acid is prepared from crystallized ferrous sulphate, $SOHoFeo'',6OH_2$, which is first well dried to drive off most of the water of crystallization, and then distilled at a red heat in an earthenware retort. It fumes in moist air, and is used for dissolving indigo, and for preparing sulphuric anhydride.

227. **Properties.** — Sulphuric acid is a colourless liquid, with an oily appearance. It has a great affinity for water. Organic substances are rapidly charred and destroyed by it. It is a very powerful acid.

228. **Uses.**—It is used for bleaching, for dissolving indigo, dyeing, calico printing, in the manufacture of soda from common salt, and for various other purposes.

Sc. Ex., 1868, A.—Describe the process of manufacturing sulphuric acid, and express the different chemical changes by equations. 225.

Sc. Ex., 1861.—Give an outline of the manufacture of sulphuric acid. 225.

CONVERSION
OF
THERMOMETRIC SCALES.

229. To convert Centigrade (C) degrees into Fahrenheit (F).

Multiply by 9, divide by 5, and add 32.

Examples—Convert 60°C. and −29°C. into Fahrenheit degrees.

$$\frac{60\times 9}{5}=\frac{540}{5}=108\text{; and } 108+32=140°\text{F.}$$

$$\frac{-20\times 9}{5}=\frac{-180}{5}=-36\text{; and } -36+32=-4°\text{F.}$$

(2) To convert Centigrade degrees into Reaumur (R).

Multiply by 4, and divide by 5.

Examples.—Convert 20°C. and −12°C. into Reaumur degrees.

$$\frac{20\times 4}{5}=\frac{80}{5}=16°\text{R.}$$

$$\frac{-12\times 4}{5}=\frac{-48}{5}=-9{\cdot}6°\text{R.}$$

(3) To convert Fahrenheit degrees into Centigrade.

Subtract 32, multiply by 5, and divide by 9.

Examples.—Express 50°F. and −20°F. in Centigrade degrees.

$$50-32=18\text{;}\quad \frac{18\times 5}{9}=\frac{90}{9}=10°\text{C.}$$

$$-20-32=-52\text{;}\quad \frac{-52\times 5}{9}=\frac{-260}{9}=-28{\cdot}8°\text{C.}$$

(4) To convert Fahrenheit degrees into Reaumur.

Subtract 32, multiply by 9, and divide by 4.

Examples. — Convert 40°F. and 16°F. into Reaumur degrees.

$$40-32=8;\ \frac{8\times 9}{4}=\frac{72}{4}=18°\text{R.}$$

$$16-32=-16;\quad \frac{-16\times 9}{4}=\frac{-144}{4}=-36°\text{R.}$$

(5) To convert Reaumur degrees into Centigrade.

Multiply by 5, and divide by 4.

Example.—Express 28°R. in Centigrade degrees.

$$\frac{28\times 5}{4}=\frac{140}{4}=35°\text{C.}$$

(6) To convert Reaumur degrees into Fahrenheit.

Multiply by 9, divide by 4, and add 32.

Example.—Convert 36°R. into Fahrenheit degrees.

$$\frac{36\times 9}{4}=\frac{324}{4}=81;\quad 81+32=113°\text{F.}$$

ARITHMETICAL QUESTIONS

WITH SOLUTIONS.

230

Sc. Ex., 1870, E.—One litre of nitrogen gas, measured at 0°C, and 760 m.m. mercurial pressure, weighs 14 criths; what is the weight in grains of one cubic metre of the same gas measured at the same temperature and pressure?

1 cubic metre (1000 litres) of nitrogen gas will weigh $1000\times 14=14000$ criths.

As ·0896 gramme is the weight of one **crith**, 14000 criths will weigh ·0896 × 14000 = 1254·4 grammes.

Then as one gramme weighs 15·434 **grains**, the 1254·4 grammes will weigh 15·434 × 1254·4 = 19360·4096 grains.

Sc. Ex., 1870, E.—What is the specific gravity of ammonia, that of hydrogen being taken as unity?

3 volumes of hydrogen and 1 volume of nitrogen combine, and condense to 2 volumes of **ammonia**, NH_3.

$$\text{Specific gravity of H} = 1$$
$$\text{,,} \qquad N = 14$$
$$\therefore \quad \text{,,} \qquad NH_3 = \frac{(1 \times 3) + 14}{2} = \frac{17}{2} = 8{\cdot}5$$

Sc. Ex., 1870, A.—How much hydrogen by weight and by volume (in litres) is required to reduce 25 grammes of ferric oxide (Fe^2O^3) to metallic iron?

By the equation,—

$$Fe_2O_3 + 3H_2 = 2Fe + 3OH_2$$

we see that (112 + 48) or 160 parts of ferric oxide are reduced by 6 parts of hydrogen.

160 grammes, Fe_2O_3 require 6 grammes of hydgn.

$$1 \text{ gramme} \quad \text{,, requires } \frac{6}{160} \quad \text{,,} \qquad \text{,,}$$

$$\therefore 25 \text{ grammes} \quad \text{,, require } \frac{6}{160} \times 25 = {\cdot}9375 \text{ gms.}$$

Dividing by ·0896 the weight of a litre of hydrogen, we have—

$$\frac{{\cdot}9375}{{\cdot}0896} = 10{\cdot}46 \text{ litres.}$$

Sc. Ex., 1869, E.—What is the per-centage composition of a substance, the formula of which is $N^2O^3H_4$?

By the formula, $N_2 = 28$; $O_3 = 48$, and $H_4 = 4$. And $28 + 48 + 4 = 80$.

	$N_2O_3H_4$		$N_2O_3H_4$		N		N		Per-centage composition
∴ As	80	:	100	: :	28	:	x	=	35 of N
					O		O		
	80	:	100	: :	48	:	x	=	60 of O
					H		H		
	80	:	100	: :	4	:	x	=	5 of H
									100

Sc. Ex., 1869, E.---I take equal volumes (measured at the same temperature and pressure) of hydrogen, nitrogen, hydrochloric acid gas, steam, and carbonic anhydride (carbonic acid), and find that the nitrogen weighs 56 grammes. Required the weight of each of the other gases.

The densities of all compounds being equal to half their molecular weight, the densities of the compounds will be found as follows :—

$\overset{H}{1} + \overset{Cl}{35{\cdot}5} = \overset{HCl}{36{\cdot}5}$ which being ÷ by 2 gives 18·25.

$\overset{O}{16} + \overset{H_2}{2} = \overset{OH_2}{18}$ „ „ 2 „ 9

$\overset{C}{12} + \overset{O_2}{32} = \overset{CO_2}{44}$ „ „ 2 „ 22

As $\overset{N}{14} : \overset{N}{56} :: \overset{HCl}{18{\cdot}25} : \overset{HCl}{x} = 73$ grammes of HCl

$\overset{N}{14} : \overset{N}{56} :: \overset{OH_2}{9} : \overset{OH_2}{x} = 36$ „ Steam (OH_2)

$\overset{N}{14} : \overset{N}{56} :: \overset{CO_2}{22} : \overset{CO_2}{x} = 88$ „ CO_2

$\overset{N}{14} : \overset{N}{56} :: \overset{H}{1} : \overset{H}{x} = 4$ „ H

Sc. Ex., 1869, E.---If 50 grammes of sodium be heated in a current of hydrobromic acid gas until it is completely converted into sodic bromide (bromide of sodium), what will be the weight and volume of the hydrogen liberated?

By the equation—$\underset{46}{Na_2} + 2HBr = \underset{\text{sodic bromide.}}{2NaBr} + \underset{2}{H_2}$

we see that two parts of hydrogen are liberated when 46 parts of sodium (Na) are heated in HCl.

Na Na H H

$\therefore$ As 46 : 50 :: 2 : x=2·173 grammes of H.

$$\therefore \text{ Volume} = \frac{2{\cdot}173}{{\cdot}0896} = 24{\cdot}25 \text{ litres}$$

Sc. Ex., 1869, A.---I measure 100 cubic centimetres of dry nitrogen at 10°C. and 650 millimetres mercurial pressure; what will be its volume at 0°C. and 760 millimetres pressure, and how much will it weigh in grammes?

Correction for temperature $\left\}\begin{array}{ccccccc} \text{Vols. at } 10^\circ & & \text{V. at } 0 & & \text{c.c. at } 10^\circ & & \text{c.c. at } 0^\circ \\ 273+10 & : & 273 & :: & 100 & : & x \end{array}\right.$

Correction for pressure $\left\}\begin{array}{ccccccc} \text{m.m.} & & \text{m.m.} & & \text{c.c. at } 10^\circ \text{ and } 650 \text{ mm} & & \text{c.c. at } 0^\circ \text{ and } 760 \text{ m.m.} \\ 760 & : & 650 & :: & x & : & x' \end{array}\right.$

$$\therefore x' = \frac{273 \times 100}{288} = \frac{650}{760} = 82{\cdot}5 \text{ no. of cubic centimetres at } 0^\circ\text{C and m.m. pressure.}$$

Again, 1 litre of H at 0°C and 760 m.m. weighs ·0896 gramme, and one litre of N at 0°C. and 760 m.m. weighs ·0896 × 14 = 1·2544 gramme

and 1 c.c. of N. weighs $\frac{1{\cdot}2544}{1000}$

$$\therefore 82{\cdot}5 \text{ c.c. will weigh } \frac{1{\cdot}2544 \times 82{\cdot}5}{1000} = 1{\cdot}03488 \text{ gms.}$$

Sc. Ex., 1869, A.—What is the theoretical quantity of pure nitric acid obtainable from one ton of sodic nitrate?

By the equation,—

$$\underbrace{NO_2Nao}_{\substack{14+32+23+16 \\ 85}} + SO_2Ho_2 = \underbrace{NO_2Ho}_{\substack{14+22+1+16 \\ 63}} + SO_2HoNao$$

we see that 63 parts of nitric acid are obtained from 85 parts of sodic nitrate.

$$\begin{array}{lllll} & NO_2Nao & NO_2Nao & NO_2Ho & NO_2Ho \\ \therefore \text{As} & 85 \ : & 1 \quad :: & 63 \ : & x = \cdot 7411 \text{ ton} \end{array}$$

Sc. Ex., 1869, A.—An analysis of a mineral gave the following numbers :—

Silicon	26·27
Calcium	18·43
Magnesium	11·06
Oxygen	44·24
	100.00

Give the empirical formula of this mineral.

(1) Divide the per-centage of each element by its atomic weight, to obtain the number of atoms of each :—

$$\frac{26{\cdot}27}{28{\cdot}25} = \cdot 92 \text{ atom of silicon.}$$

$$\frac{18{\cdot}43}{40} = \cdot 46 \quad \text{,,} \quad \text{calcium}$$

$$\frac{11{\cdot}06}{24} = \cdot 46 \quad \text{,,} \quad \text{magnesium}$$

$$\frac{44{\cdot}24}{16} = 2{\cdot}76 \text{ atoms of oxygen}$$

(2) Find three *whole* numbers in the ratio of ·92 : ·46 : 2·76. To do this, divide each by the lowest :—

$$\frac{\cdot 92}{\cdot 46} = 2\ ; \quad \frac{\cdot 46}{\cdot 46} = 1\ ; \quad \frac{2{\cdot}76}{\cdot 46} = 6$$

Thus we find that there is one atom each of calcium and magnesium, two atoms of silicon, and six atoms of oxygen. The empirical formula is—$Si_2Ca\ MgO_6$.

Sc. Ex., 1868, E.—A normal or neutral salt of sulphuric acid and a diad metal contains 21·05 per cent. of sulphur, and 36·84 per cent. of metal. What is the atomic weight of the metal?

By the equation,—

$$SO_2Ho_2 + M = SO_2Mo'' + H_2$$

Sulphuric acid Metal Sulphate

we learn that there is one atom of the metal, and one atom of the sulphur; therefore, as the percentage of sulphur is to be the per-centage of the metal, so will the atomic weight of sulphur be to the atomic weight of the metal:—

Or, as 21·05 : 36·84 :: 32 : x=56 atomic weight of metal.

The metal is iron (Fe), and the salt is ferrous sulphate (SO_2Feo'').

Sc. Ex., 1868, E.—How much water would be produced from 28lbs. of oxygen and 5lbs. of hydrogen, and would either of the elements be in excess?

In water there are 8 parts of oxygen to 1 part of hydrogen; therefore, the quantity of hydrogen required for 28lbs. of oxygen will be found by dividing 28 by 8, thus:—

$$\frac{28}{8} = 3{\cdot}5\text{lbs},$$

Then as there are 5lbs, of hydrogen, and only 3·5lbs. required, the excess of hydrogen would be 5 − 3·5=1·5lbs.

Sc. Ex,, 1868, E.—You are required to convert 1lb. of silver into argentic nitrate (nitrate of silver); how will you do it. and what will be the weight of nitrate produced?

The silver is converted into argentic nitrate by dissolving it in nitric acid.

By the equation,—

$$\underset{108}{Ag} + \underset{\text{Nitric acid}}{NO_2Ho} = \underbrace{NO^2Ago}_{\underbrace{14+32+108+16}_{170}} + H$$

we see that 108 parts of silver produce 170 parts of argentic nitrate.

$$\therefore \text{ As } \underset{108}{\overset{Ag}{}} : \underset{1}{\overset{Ag}{}} :: \underset{170}{\overset{\text{Nitrate}}{}} : \overset{\text{Nitrate}}{x} = 1{\cdot}57\text{lbs. of}$$

argentic nitrate.

Sc. Ex., 1868, E.—A compound of iron and oxygen contains 72·4 per cent. or iron, and 27·6 per cent. of oxygen; what is its formula?

(1) Divide the per-centage of each element by its atomic weight, to obtain the number of atoms each:— $\frac{72{\cdot}4}{55}=1{\cdot}29.\quad \frac{27{\cdot}6}{16}=1{\cdot}72$

(2) Find two *whole* numbers in the ratio of 1·29 : 1·72. To do this, first divide each number by the smaller one:—

$$\frac{1{\cdot}72}{1{\cdot}29}=1{\cdot}33=\frac{1{\cdot}29}{1{\cdot}29}=1$$

Now multiply by 3 to get rid of ·33, and we have 3 atoms of iron and 4 atoms of oxygen. The formula therefore is—Fe_3O_4 (Magnetic oxide).

Sc. Ex., 1868, E.—If a given volume of hydrogen weighs 20 grains, how much will the same volume of carbonic acid gas weigh at the same temperature and pressure?

The specific gravity of carbonic acid gas (CO_2) is found thus:—

$$\frac{12+32}{2}=\frac{44}{2}=22$$

∴ As the specific gravity of CO_2 is 22 times that of H, the same volume of CO_2 will weigh 22 times as much as the hydrogen, or $20+22=440$ grs.

Sc. Ex., 1868, A.—A gas measures 117·9 cubic inches at 9°9C., and 700·9 millimetres mercurial pressure. Required its volume at 0°C., and one metre mercurial pressure

				cu. in. at 9°9		cu. in. at 0°
Correction for temperature	Vols at 9°9		Vols at 0			
	273+9·9	:	273	:: 117·9	:	x

				cu. in. at 9°9 and 700·9 m.m.		cu. in. at 0° and 1 metre
Correction for pressure.	metre		m.m. m.m.			
	1 or 1000	:	700·9	:: x	:	x

$$\therefore x' = \frac{273\times117\cdot9}{282\cdot9}\times\frac{700\cdot9}{1000} = 79\cdot741.$$ number of cu. in. at 0°C and 1 metre pressure.

Sc. Ex., 1868, A.—How much white marble would you require to produce 1 cwt. of chloride of calcium, and what other material would be necessary for the transformation? Express the chemical change by an equation.

The chemical change is denoted by the following equation:—

Calcic carbonate (marble)			Chloride of calcium		
$COCao''$	$+\ 2HCl =$		$CaCl_2$	$+\ CO_2 +$	OH_2
$\underbrace{12+16+42+32}_{100}$			$\underbrace{40+71}_{111}$		

By the equation we see that 100 parts of marble produce 111 parts of chloride of calcium.

	$CaCl_2$		$CaCl_2$		Marble		Marble
∴ As	111	:	112	::	100	:	x=100·9lbs.

Sc. Ex., 1868, A.—An analysis of a salt gave the following numbers; what is its empirical formula?

Sulphur	22·53
Sodium	32·39
Oxygen	45·08
	100·00

(1) Divide the per-centage of each element by its atomic weight, to obtain the number of atoms each:—

$$\frac{22 \cdot 53}{32} = \cdot 7 \text{ atom of sulphur}$$

$$\frac{32 \cdot 39}{23} = 1 \cdot 4 \text{ atoms of sodium}$$

$$\frac{45 \cdot 08}{16} = 2 \cdot 8 \text{ atoms of oxygen}$$

(2) Find three *whole* numbers in the ratio of $\cdot 7 : 1 \cdot 4 : 2 \cdot 8$, and to do this divide each by the lowest:—

$$\frac{\cdot 7}{\cdot 7} = 1 \; ; \; \frac{1 \cdot 4}{\cdot 7} = 2 \; ; \quad \frac{2 \cdot 8}{\cdot 7} = 4$$

Thus we find that there is one atom of sulphur, two atoms of sodium, and four atoms of oxygen. The empirical formula therefore is—Na^2SO_4.

Sc. Ex., 1867, E.—How many grammes of oxygen can be separated from 100 grammes of binoxide of manganese by heat; and how many by the action of sulphuric acid?

(1) By the equation,—

$$\underbrace{3(55+32)}_{261}\!\!\!\!\!\!\!\!\!\!\!\! 3MnO_2 = Mn_3O_4 + \underset{32}{O_2}$$

we see that 32 parts of oxygen are separated from 261 parts of binoxide of manganese by heat.

$$\begin{array}{llll} MnO_2 & MnO_2 & O & O \end{array}$$

$\therefore$ As $261 : 100 :: 32 : x = 12 \cdot 26$ grammes of O.

(2) By the equation,—

$$2MnO_2 + 2SO_2Ho_2 = 2OH_2 + 2SO_2Mno'' + O_2$$

$$\underbrace{2(55+32)}_{174}$$

we find that 32 parts of oxygen are separated from 174 parts of binoxide of manganese by the action of sulphuric acid.

$$\begin{array}{lllll} & MnO_2 & MnO_2 & O & O \\ \therefore \text{As} & 174 & : 100 :: & 22 : & x = 18{\cdot}39 \text{ grammes of O.} \end{array}$$

Sc. Ex., 1867, E.—In 100 parts by weight of common salt how many parts by weight of chlorine?

By the equation,—

$$Na + Cl = NaCl \text{ (common salt)}$$
$$23 + 35{\cdot}5 = 58{\cdot}5$$

we learn that there are 35·5 parts by weight of chlorine in every 58·5 parts by weight of common salt.

$$\begin{array}{lllll} & NaCl & NaCl & Cl & Cl \\ \therefore \text{As} & 58{\cdot}5 & : 100 :: & 35{\cdot}5 : & x = 60{\cdot}68 \text{ of chlorine} \end{array}$$

Sc. Ex., 1867, A.—100 litres of phosphoretted hydrogen (H_3P) at 100°C are mixed with 300 litres of chlorine at 100°C; how many litres of chloride of phosphorus gas, and how many litres of hydrochloric acid, both measured at 100°C, are produced.

By the equation,—

$$\begin{array}{lllll} & PH_3 + & 3Cl_2 = & 3HCl + & PCl_3 \\ \text{Volumes} & 2 & 6 & 6 & 2 \end{array}$$

we see that from two litres of phosphoretted hydrogen, 2 litres of chloride of phosphorus gas (PCl_3) and 6 litres of hydrochloric acid are formed. Therefore from 50 times this quantity (100 litres) of phosphoretted hydrogen, 50 times the quantity of chloride of phosphorus gas and of hydrochloric acid will be formed; that is, 100 litres of phosphoretted hydrogen will give 100 litres of chloride of phosphorus gas and 300 litres of hydrochloric acid.

THE END.

ERRATA.

Page 9—For Sc. Ex., 1860, A, read Sc. Ex., 1869, A.

Page 30, line 10—For $\mathbf{P}OMO_8$ read $\mathbf{P}OMo^8$.

,, 33—For symbol of nitric peroxide $\mathbf{N}\ O^4$, read $\mathbf{N}_2O_4$.

Page 34, line 5—For Ho_3Cl, read HO_3Cl.

,, 34, ,, 6—For Ho_4Cl, read HO_4Cl.

,, 34—For symbol of nitrous acid $\mathbf{N}oHo$, read $\mathbf{N}OHo$.

Page 41—Instead of the numbers 124 and 135 (4) at the end of the second question, read 124 (1) and (3); and 135 (6).

Page 47—Instead of the number 135 (4) at the end of the third question, read 124 (1) and (3); and 135 (6).

Page 57, line 1—For $\mathbf{S}O_2H_2$, read $\mathbf{S}O_2Ho_2$.